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Request for grant of a patent

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1. Your reference
5424801/NRPF

0215764.2 er 8 JUL 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Vision RT Limited
5 Broadlands Close
London
N6 4AF

8420317001

Patents ADP number *(if known)*

If the applicant is a corporate body, give the country/state of its incorporation

Country: **Great Britain**
State:

4. Title of the invention

Image Processing System For Use With A Patient Positioning Device

5. Name of agent

Beresford & Co

"Address for Service" in the United Kingdom to which all correspondence should be sent

2/5 Warwick Court
High Holborn
London WC1R 5DH

Patents ADP number

1826001

6. Priority details

Country	Priority application number	Date of filing

Patents Form 1/77

7. If this application is divided or otherwise derived from an earlier UK application give details

Number of earlier application | Date of filing

8. Is a statement of inventorship and or right to grant of a patent required in support of this request?

Yes

9. Enter the number of sheets for any of the following items you are filing with this form.

Continuation sheets of this form	-
Description	64
Claim(s)	25
Abstract	1
Drawing(s)	11

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents form 7/77)*	-
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for Substantive Examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. I/We request the grant of a patent on the basis of this application

Signature Beresford & Co
BERESFORD & Co

Date 8 July 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

FOX; Nicholas

Tel: 020 7831 2290

IMAGE PROCESSING SYSTEM FOR USE WITH A PATIENT POSITIONING DEVICE

The present invention relates to image processing. More particularly, embodiments of the present invention relate to image processing systems for use with patient positioning devices.

One application of the present invention is in the field of radiotherapy. Radiotherapy consists of projecting onto a predetermined region of a patient's body, a radiation beam so as to destroy or eliminate tumours existing therein. Such treatment is usually carried out periodically and repeatedly. At each medical intervention, the radiation source must be positioned with respect to the patient in order to irradiate the selected region with the highest possible accuracy to avoid radiating adjacent tissue on which radiation beams would be harmful.

To this end, radiotherapy usually takes place in two stages. In an initial planning stage the patient's body is scanned using a 2-D x-ray simulator or a CT simulator, or by Magnetic Resonance Imaging (MRI) to visualise the target site and any obstacles. The course of therapy is

then planned using the images obtained from the x-ray scanner or using the MRI images. Subsequently in a treatment stage a patient is irradiated in accordance with the course of treatment planned during the planning stage.

A fundamental problem with radiotherapy is the need to position the patient in the same position, when obtaining diagnostic images and each of the subsequent times when radiation is applied to the patient's body. Present systems for positioning patients include various forms of systems for placing markers on the patient to enable the patient to be realigned for different applications of therapy. Thus for example US 5954647 discloses the use of a specially moulded bite plate on which LED's are placed to enable the head of an individual to be orientated in the same position in which diagnostic images are obtained. Similarly US 5446548 describes another positioning and monitoring system. The system of US 5446548 involves the fixing of infra-red reflective markers on parts of a patient's body.

Although known systems involving the tracking of markers fixed relative to the patient enable the patient's positioning to be monitored, it is desirable to be able

to determine the patient's position more accurately to increase the effectiveness of treatment. Further, it is desirable to provide a positioning system which minimises the extra time required and the inconvenience to a patient arising from placing or fixing markers and thus reduces the stresses placed upon the patient during treatment.

In accordance with one aspect of the present invention there is provided a patient positioning system in which a three-dimensional model of the surface of a patient is generated utilising a number of stereoscopic video images of the patient. The video images are processed to generate the three dimensional model which is rapidly updated to account for changes in the position of the patient.

In order to enable the surface model of a patient to be updated as rapidly as possible a number of techniques are utilised. In accordance with one aspect there is provided an image processing method comprising the steps of:

obtaining stereoscopic images of an individual;

generating a surface model of said individual utilising said stereoscopic images;

receiving further stereoscopic images of said individual and generating a further model of said individual from said further stereoscopic images and said previous model of said individual.

In accordance with a further aspect of the present invention there is provided a method of image processing comprising the steps of:

obtaining a first and a second image of an individual from a first and a second view point;

identifying within said first and said second images, portions of said images corresponding to the same points on the surface of said individual; and

for said points on said surface of said individual, determining the orientation of the surface of said individual at said points relative to said view points, wherein said determination of said orientations relative to said view points comprises:

determining the orientation of a point on the surface of said individual;

for adjacent points on the surface of said individual for which said orientation has not been determined, determining whether said determined orientation for said point is a better estimate of the orientation of said adjacent points than a current

estimate of orientation for said adjacent points; and

if said determined orientation is a better estimate than said current estimate, updating said current estimate for said adjacent points; and

determining said orientation for said adjacent points utilising the best estimate of said orientation determined from said orientations for adjacent points.

Further aspects and embodiments of the present invention will become apparent with reference to the following description and accompanying drawings in which:

Figure 1 is a schematic diagram of a first embodiment of the present invention;

Figure 2 is a perspective view of a camera rig of Figure 1;

Figure 3 is a block diagram of the computer of Figure 1;

Figure 4 is a an overview flow diagram of the processing of the computer of Figure 1;

Figure 5A is an illustration of a calibration device utilised to calibrate the positioning system of Figure 1;

Figure 5B is an exemplary illustration of an image obtained utilising the calibration device of Figure 5A;

Figure 6 is a flow diagram of the processing of the

computer of Figure 1 for generating models of individuals from received images;

Figures 7A and 7B are a flow diagram of the processing of the computer of Figure 1 for matching points in received images to determine the orientation of points on the surface of an individual;

Figure 8 is a schematic illustration of a data structure for storing data utilised to perform the processing of Figures 7A and 7B;

Figure 9 is a flow diagram of the processing of the computer of Figure 1 to generate a model of the surface of an individual; and

Figure 10 is a schematic block diagram of a camera for use in a second embodiment of the present invention.

First Embodiment

Figure 1 is a schematic diagram of a first embodiment of the present invention. In accordance with this embodiment, there is provided a set of three camera rigs 1, 2, 3 that are connected by wiring 4 to a computer 5. The computer 5 is also connected to treatment apparatus 6 such as a linear accelerator for applying radiotherapy or an x-ray simulator for planning radiotherapy. A mechanical couch 7 is provided as part of the treatment apparatus 6 upon which a patient 8 lies during treatment. The treatment apparatus 6 and the

mechanical couch 7 are arranged such that under the control of the computer 5 the relative positions of the mechanical couch 7 and the treatment apparatus 6 may be varied, laterally, vertically, longitudinally and rotationally. Also provided as part of the system is a laser projection apparatus 9 which is arranged to project three laser cross hairs 10 onto the body of a patient 8 lying on the mechanical couch 7 where the three laser cross hairs 10 are such to identify the focussing point of the radiation generated by the treatment apparatus 6.

In use, the cameras of the camera rigs 1, 2, 3 obtain video images of a patient 8 lying on the mechanical couch 7. These video images are passed via the wiring 4 to the computer 5. The computer 5 then processes the images in accordance with the present invention to generate a three-dimensional model of the surface of the patient, which is displayed on the screen 11 of the computer 5. The three-dimensional model of the patient is then continually updated utilising the stream of video images obtained from the cameras of the camera rigs 1, 2, 3. The three-dimensional models of the surface of a patient 8 are also utilised by the computer 5 to control the treatment apparatus 6 to position the mechanical couch 7 relative to the treatment apparatus 6 in a consistent

manner throughout the course of a treatment.

Prior to describing in detail the image processing algorithms utilised to generate and vary the three-dimensional model of the surface of a patient 8, the structure of the camera rigs 1, 2, 3 will first be described in detail with reference to Figure 2.

Figure 2 is a schematic illustration of one of the set of camera rigs 1, 2, 3 of this embodiment of the present invention. All of the camera rigs 1, 2, 3 in this embodiment are identical to the others with the three camera rigs 1, 2, 3 being arranged with one either side of the mechanical couch 7 and one at the head of the mechanical couch 7. The arrangement of cameras of the rigs 1, 2, 3 are such that all the cameras of the camera rigs view substantially the same portion of the patient immediately beneath the treatment apparatus 6 so that a complete model of that portion of the patient 8 can be generated.

The camera rigs 1, 2, 3 each comprise a T-bar 12 which is suspended from the roof of the room within which the treatment apparatus 6 is provided. To this end a base plate is provided at the top of the T-bar 12 with the

main body of the T-bar 12 extending down from the centre of this base plate. Provided in each of the corners of the base plate 14 are fixing holes 15 through which bolts pass to fix the T-bar 12 in position in the room containing the treatment apparatus 6.

Provided at the opposite end of the T-bar 12 to the base plate 14 attached to the horizontal cross bar 16 forming the T-section of the T-bar are three cameras 18,22,24. These cameras 18,22,24 are arranged along the cross bar 16, and in order from left to right along the cross bar 16 are a first geometry camera 18, a texture camera 20 and a second geometry camera 22. The cameras 18, 20, 22 each comprise monochrome analogue video cameras such as the Pulnix PE100.

Provided in front of the lenses of each of the cameras is are filters 24, 26, 28. The filters on the two geometry cameras 18, 22 are arranged to prevent the geometry cameras 18,24 from receiving light having a wavelength below 570 nm. The filter 26 in front of the lens of the texture camera 20 comprises a filter preventing the texture camera 20 from receiving light with a wavelength greater than 540 nm.

Each of the cameras 18, 20, 22 is attached to the horizontal bar 16 of the T-bar 12 by a clamp 30 which attaches the cameras 18, 20, 22 to the horizontal cross bar 16 of the T-bar 12, whilst permitting the orientation of the cameras 18, 20, 22 relative to the horizontal bar 16 of the T-bar 12 to be adjusted.

Also attached to the horizontal bar 16 of the T-bar 12 by further clamps 30 are a first 32 and second 34 light source. In this embodiment the first light 32 source comprises a light source arranged to irradiate light having a wavelength greater than 570 nm and being arranged to project onto the surface of a patient 8 lying on the mechanical couch 7 of the treatment apparatus 6 a random speckle pattern. An example of a suitable light source would be a slide and slide projector, where the slide bears a non-repeating speckle pattern and the slide projector comprises a filtered light source filtered to prevent light with a wavelength less than 570 nm from being projected onto the slide.

The second light source 34 comprises a conventional light bulb with a filter to allow light with a wavelength of less than 540 nm to pass. The second light source 34 is also arranged to illuminate the portion of a patient 8

which is visible from the cameras 18, 20, 22. The filtration of the light from the second light source 34 prevents the light from the second light source 34, interfering and saturating the speckle pattern generated by the first light source 32.

In use, images of the speckle pattern are obtained by the geometry cameras 18, 22 as these cameras are arranged to detect light having a frequency of greater than 570 nm. These images from the geometry cameras 18, 22 are then subsequently processed so that the position and orientation of the surface of the body of the patient 8 visible from the geometry cameras 18, 22 can be determined and a three dimensional model of the surface of the individual generated as will be described later.

When a textured rendered model of a patient is desired, the images of the patient are obtained from the texture camera 20. These images are then utilised to texture render the model created from the geometry camera 18, 22 images. As the texture camera 20 is arranged only to detect light having a wave length in less than 540 nm, this image does not contain the speckle pattern projected by the first light source 32 but rather corresponds to the visible images perceived by an operator within the

treatment room.

Figure 3 is a schematic block diagram of the computer 5 of Figure 1. The computer 5 comprises a microprocessor 38 and memory 40. The memory 40 is configured into a number of notional functional modules.

In this embodiment, these functional modules comprise a processing module 42 for controlling the microprocessor 38 to co-ordinate receiving and processing images; a control module 44 arranged to control the microprocessor 38 to receive signals from the keyboard of the computer 5 and co-ordinate the processing by the processing of the other modules; a calibration module 43 enabling microprocessor 38 to calibrate the positioning system so that relative to the point of focus of the treatment apparatus 6 as identified by the laser beam cross hairs 10, the processing module 42 is able to identify the location of the surface of a patient 8; a mechanical couch control module 45 arranged to enable the microprocessor 38 to utilise generated surface models of an individual to generate positioning instructions which are then passed to the mechanical couch 7 of the treatment apparatus 6 so that a patient 8 may be automatically correctly positioned for treatment; an

image generation module 46 to enable the microprocessor 38 to generate an image of the portion of the patient being treated and display it on the screen 11 of the computer 5; and a data store 47.

Also provided as part of the computer 5 are a video sync unit 50 and a first and a second frame grabber 51, 52. The first and second frame grabbers 51, 52 are arranged to receive image data from the three cameras attached to each of the camera rigs 1, 2, 3, specifically the first and second frame grabbers 51, 52 are arranged to receive video signals from the geometry cameras 18, 22 of the camera rigs 1, 2, 3 via the video sync 50. Video images for the six geometry cameras (two cameras on each of the three camera rigs) are received by the video sync 50 and passed to the two frame grabbers 51, 52, three to the first frame grabber 51 and three to the second frame grabber 52. The video sync 50 passes timing signals from the first frame grabber 51 to the second frame grabber 52 to ensure that image data from the geometry cameras 18, 22 is acquired simultaneously. By providing two frame grabbers 51, 52, in this way the computer 5 is arranged to receive image data from the geometry cameras 18, 22 of all three rigs 1, 2, 3 simultaneously so that an instantaneous three dimensional model of the surface

of a patient 8 can be generated.

Periodically, when requested by the control module 44, the video sync 50 is arranged to obtain image data from the texture cameras 20 of the camera rigs 1,2,3. When a frame of image data from these other cameras is received by the video sync 50 they are passed to the first frame grabber 51, and then onto the processing module 42. These images which comprise images generated from light having a wavelength less than 540 nm are then subsequently used to texture render the three dimensional model generated by the image generation module 46. In contrast to the geometry camera images received simultaneously for a particular frame, the texture camera images represent an images from the subsequent frame separated by approximately 40 milliseconds from the geometry camera images, utilised to generate a three dimensional model. However, as the appearance of the surface of an individual 8 varies very little over this time period, this mismatch in timing does not appreciably diminish the performance of the system. In contrast, simultaneous geometry camera images from all the geometry cameras are required to enable a highly accurate model of the surface of a patient 8 to be calculated.

The overall processing of the computer 5 will now be described in detail. Figure 4 is a flow diagram of the processing of the computer 5 in accordance with this embodiment of the present invention. Initially a user via the keyboard of the computer 5 identifies to the control module 44 that the computer 5 is to process the images received from the three camera rigs 1, 2, 3 to generate a set of calibration parameters to identify the relative positioning of the cameras 18, 20, 22 on each of the rigs 1, 2, 3. When such an instruction is received from the keyboard the calibration module 43 is invoked and camera calibration (S1) is then performed.

A calibration sheet comprising a 40 x 40 cm sheet of flat rigid material such as aluminium or steel on which a pattern revealing a 20 x 20 matrix of circles at known positions on the surface of the sheet is provided. Additionally, towards the centre of the calibration sheet are four smaller markers adjacent to four circles the centres of which together identify the four corners of a square of known size. When calibration is to occur, the sheet is held in position on the mechanical couch 7. Images of the calibration sheet are then obtained by all of the cameras 18, 20, 22 of a camera rig 1, 2, 3 being calibrated. These images are then processed by the

calibration module 43 by initially performing a thresholding operation on the obtained images. The thresholded images are then processed to identify within the image the positions of the four markers in the images and their associated circles. This can be done either automatically using conventional techniques or alternatively, a user may identify the four circles manually.

From the relative positions of circles identified by the markers in the images, a projective transformation is determined which accounts for the estimated centres of the identified circles defining the corners of a parallelogram in the image which arises due to the relative orientation of the calibration sheet and the camera obtaining the image. In this embodiment the transformation determined is an estimated transformation for distorting the image so that the circle centres correspond to the corners of a perfect square.

The calculated transform is then applied to each of the identified circles in turn to transform the oval shapes of the circles. A more accurate estimate of the positions of the centres of the four circles is then determined by identifying the centre of the transformed

circles and utilising an inverse transform to determine the corresponding position of the estimated circle centre in the original image. These updated estimates are then revised to determine a new transformation. By repeating the process a number of times an accurate estimate of the transform required to account for the relative orientation of the calibration sheet can be made,

Using the determined transform, the expected positions of all of the circles on the sheet appearing in the image are then calculated, the portions of the images in the vicinity of each of the estimated circle centres are then processed individually. Firstly, from the threshold image, the portion of an image corresponding to a circle on the calibration sheet is identified. The identified area is then subjected to the calculated transform so as to transform the elliptical appearance of the circle in an image due to the relative orientation of the calibration sheet to the camera being calibrated. The actual centre of the transformed circle is then determined in a similar manner as has previously been described and then the projection of that actual centre appearing in the image is then calculated by applying the inverse of the calculated transform to the co-ordinates of the newly estimated circle centre.

When the co-ordinates for all the centres of each of the representations of the circles on the calibration sheet have been calculated for an image, the relative orientation of the different cameras 18, 20, 22 on one of the camera rigs 1, 2, 3 can then be calculated from the relative positions of these points in the images and the known relative locations of these circles on the surface of the calibration sheet as is described in detail in "A Versatile Camera Calibration Technique for High-Accuracy 3D Machine Vision Metrology Using Off the Shelf TV Cameras and Lenses", Roger Tsai, IEEE Journal of Robotics and Automation, Vol. Ra-3, No.4, August 1987. Further from the relative positions of the points in the individual images internal camera parameters such as the focal length, and radial distortion within the camera images can also be determined. This information is then stored within the data store 47 of the memory 40 of the computer 5 for use in subsequent generation of accurate three dimensional representations of the surface of a patient.

When the camera positions and internal camera parameters have been determined for all of the cameras 18, 20, 22 for all three of the camera rigs 1, 2, 3, the positioning of the cameras relative to the focussing point of the

treatment apparatus 6 is then determined (S2).

In this embodiment as has previously been described a laser projection system 9 is provided which is arranged to project three cross hairs 10 identifying the focussing point of the treatment apparatus 6. This focussing point is also known as the isocentre for the treatment apparatus 6. In a conventional manner the calibration of this laser equipment and the treatment apparatus 6 is performed so that a user is able to use the projection of the laser cross hairs 10 being planes of light which intersect at the isocentre to identify the isocentre of the treatment apparatus 6 when treatment is occurring. The laser cross hairs 10 are then utilised to enable the relative positions of the cameras of the camera rigs 1, 2, 3 to be determined relative to the isocentre.

Specifically as is illustrated in Figure 5A, a calibration cube comprising a cube of known size on whose surfaces are a series of thin black and white stripes is placed on the mechanical couch 7 in the vicinity of the focussing point of the treatment apparatus 6. As can be seen from Figure 5A the stripes on the calibration cube are oblique relative to the sides of the cube. The illumination within the treatment room is then switched

off so that the cube is only illuminated by the cross hairs generated by the laser projection apparatus 9. Images of the cube illuminated in this manner are then obtained by the cameras 18, 20, 22 in each of the camera rigs 1, 2, 3.

Figure 5B is an exemplary illustration of an image obtained by one of the cameras of the calibration cube illuminated only by the cross hairs generated by the laser projection apparatus 9. As can been seen in Figure 5B the image comprises a number of discrete points corresponding to portions of the cross hairs which are reflected by the white stripes on the calibration cube.

Processing pairs of images obtained by the geometry cameras 18, 22 from a camera rig 1, 2, 3 and the known relative orientation and internal parameters of the cameras 18, 22 on each rig, enables three dimensional co-ordinates of the points appearing in the images relative to the camera rigs 1, 2, 3 to be determined.

As these points correspond to points lying on planes intersecting with the surface of the calibration cube, groups of the points identify planes in space. The relative positioning of the cameras 18, 22, 24 and the

focussing point of the treatment apparatus 6 can then be identified by determining the point of intersection of three planes which are identified by groups of points corresponding to pairs of the identified lines 53, 54; 55, 56; 57, 58 as this will be the only point in the treatment room where all the cross hairs intersect. Data identifying the co-ordinates of the isocentre relative to each of the camera rigs 1, 2, 3 is then stored in the data store 47 of memory 40 of the computer 5 so that the relative positioning of the cameras 18, 20, 22 of the three camera rigs 1, 2, 3 relative to this isocentre can be utilised as a fixed point to identify the relative position of a patient 8 on the mechanical couch 7.

After the positions of all the cameras 18, 20, 22 of the camera rigs 1, 2, 3 have been determined relative to the focussing point of the treatment apparatus 6, the cameras 18, 20, 22 can then be utilised to generate representations of the surface of a patient 8 lying on the mechanical couch 7. In order to do so an instruction is entered via the keyboard of the computer 5. When this is detected by the control module 44, the control module 44 then causes the processing module 42 to start processing images received from the video cameras to generate a three dimensional model of the surface (S3)

received in those images. This processing continues until an instruction to stop (S4) generating images is received from the keyboard of the computer 5 at which processing of images and generation of surface models ends.

The processing of the processing module 42 for generating models of the surface of a patient 8 on the mechanical couch 7 of the treatment apparatus 6 will now be described in detail with reference to Figures 6, 7A and B, 8 and 9.

Figure 6 is a flow diagram of the processing by the computer 5 when a set of images are received by the processing module 42 from the frame grabbers 51, 52. Initially (S10) the processing module 42 determines whether the images received are the first of a set of images of the patient 8 which a model is being generated. If this is not the case, the processing module 41 will already have stored within the data store 47 data identifying the affine transformations required to match points in images obtained by one of the geometry cameras 18 of a camera rig in the corresponding image obtained by the second geometry camera 22 in the same camera rigs. If this is the case, the processing module 42 utilises

(S11) the previously stored data in the data store 47 to initialise the model data being generated for the current images. The processing module 42 then (S12) proceeds to match point appearing in images obtained by the geometry cameras 18, 22 for the first of the camera rigs 1, 2 3 as will now be described in detail with reference to figures 7A and 7B and 8.

Figures 7A and B are a flow diagram of the processing of images by the processing module.

As a first step in processing pairs of images received from the geometry cameras 18, 22 the processing module 42 initialises (S20) the matrix of match parameters identifying the manner in which points in an image obtained from one of the geometry cameras 18 are matched in points in the image received from the other geometry camera 22.

Figure 8 is a schematic illustration of a data structure for storing data utilised to match points in the images of one geometry camera 18 of a camera rig 1,2,3, to a corresponding point in images received from the other geometry camera 22 of the camera 1, 2, 3. The data structure of Figure 8 is stored in the data store 47 for

each of a matrix of points in the image of the first geometry camera 18 so that corresponding points in a corresponding image received from the other geometry camera 22 from the same camera rig can be identified.

For each of the points in the image which identify a matrix of patches in the image the following data is stored: an x coordinate 60 and a y coordinate 62 identifying the location of the image patch being matched; a current transform 64 identifying the manner in which a patch in the first image is to be distorted so as to match the corresponding portion of a matching patch in a second image; an iteration result 66 identifying the number of iterations utilised to calculate the current transform 64 or a negative code number identifying a lack of convergence; a patch difference 68 identifying the total difference in grey scale values between the patch identified by the x and y coordinates 60,62 and the corresponding patch in the other geometry image; a process count 70 identifying the number of times the point identified by the x coordinate y coordinate data 60,62 has been processed and a predict/calculated flag 72.

When the matrix of match parameters for a pair of images

is first generated for all of the pairs of x coordinates and y coordinates 60,62 the current transform 64 iteration result 66, patch difference 68, process count 70, and predict/calculated flag 72 are set as follows:

Current Transform	=	identity
Iteration Result	=	-99
Patch Difference	=	1000
Process Count	=	0
Predict/Cal Flag	=	predicted

If, however, a pair of geometry images from the camera rig 1,2,3 has already been processed, in this embodiment instead of initially setting the current transform to being the identity transform, the previously calculated transform for that point is utilised when initialising the matrix of match parameters for the next pair of images from that camera rig to be processed. In this way, the processing module 42 is arranged to assume that as an initial estimate of the surface of the patient, the shape of the patient 8 being monitored does not vary. As this is normally a reasonable first approximation, this ensures that the initial transformation selected as a starting point is to close to being correct, and hence the speed of which images can be processed is increased.

The processing module 42 then (S21) identifies the next patch in image received from a geometry camera 18 which is to be matched to a corresponding patch in a corresponding image from the other geometry camera 22 from the same camera rig 1, 2, 3. This is achieved using a conventional search, in 3D space.

Specifically, the image processing module, 42 first identifies the next patch in the image which has not been processed. This is achieved by scanning the matrix of match parameters to find an unmatched point. Using the co-ordinates of the selected patch and the relative orientations of the texture cameras 18, 22 on a camera rig, the image processing module then selects potential matches for the patch in one texture image as corresponding to the patch from the other image by calculating expected positions for the patch assuming the patch is a various depths away from the cameras. When a match for the next patch has been identified, data identifying the coordinates of this patch and a potential match are added to the bottom of the queue (S22) of patches to be processed.

The image processing module 42 then (S23) selects the patch at the head of the queue for processing. The

transformation necessary to match the selected patch with a corresponding patch in the other geometry image being processed is then determined.

In this embodiment assuming that the images, image 1 and image 2 being processed are represented by functions f and g such that:

$$\text{Image } 1 = f\ (x,y)$$
$$\text{Image } 2 = g\ (x,y)$$

In a region being matched there will exist a transform T such that $f(x_i,y_i)=g(T(x_i,y_i))$, where x_i,y_i are in region being matched.

Assuming that the transform T represents an affine transformation, which is a reasonable approximation the transformation $T(x,y)$ can be represented as:

$$T(x,y)=(ax+by+c,dx+ey+f)$$

Therefore in the regions which correspond to one another $f(x_i,y_i)=g(ax_i+by_i+c,dx_i+ey_i+f)+\epsilon$ where ϵ; is an error term which reflects noise between the images.

Values for a,b,c,d,e and f can then be determined iteratively by relacing these values by $a+\delta a$, $b+\delta b$, $c+\delta c$, $d+\delta d$, $e+\delta d$, $e+\delta e$, $f+\delta f$ and approximating the resulting non linear function by a linear expression that can be solved using a least squares matrix technique.

Thus, if $g_x(x_i',y_i')$ and $g_y(x_i',y_i')$ are the derivatives of function g in the x and y directions evaluated at the point (x_i,y_i) then from the above

$$f(x_i,y_i)-g(x_i',y_i')=$$
$$(xg_x^i\delta a+yg_x^i\delta b+g_x^i\delta c+xg_y^i\delta d+yg_y^i\delta e+g_y^i\delta f)+\epsilon$$ with $(x_i',y_i')=(ax_i+by_i+c,dx+ey_i+f)$ and $g_x(x_i',y_i')=g^i_x, g_y(x'_i,y_i')=g_y^i$

and hence in matrix form

$$f(x_i,y_i)-g(x_i',y_i')=(xg_x^i, yg_x^i, g_x^i, xg_y^i, yg_y^i, g_y^i) *(\delta a,\delta b,\delta c,\delta d,\delta e,\delta f)^T+\epsilon$$

From the above the difference between the two patches $f(x_i,y_i)$ and $g(x'_i,y'_i)$ is equal to the matrix multiplication of the two matrices on the right hand side plus the error ϵ_i; and hence $B=A\delta D+E$ where B is the difference between the two regions whose ith entry is $f(x_i,y_i)-g(x_i',y_i')$, $D=(a,b,c,d,e,f)$, $\delta D=(\delta a,\delta b,\delta c,\delta e,\delta f)$ and A is a matrix whose ith row is $(xg_x^i,yg_x^i,g_x^i,xg_y^i,yg_y^i,g_y^i)$ which is dependent upon image

derivatives and E is an error vector whose ith entry is e_i.

Assuming $\xi(E)=0$ and $\xi(EE^T)=\sigma^2P^{-1}$ where ξ is the expectation operator and σ is a numerical factor and P is a matrix $B=A\,\delta D+E$ forms a Gauss-Markov estimation model, which can be solved by pre-multiplying by A^TP so that $A^TPB=A^TPA\delta D+A^TPE$. Dropping the error term these can be solved by Cholesky Decomposition giving an unbiased, minimum variance estimator of δD.

An iterative determination of the values for a,b,c,d,e and f can therefore be made. With each iteration A should be updated to account for the new calculated transform T for the new values of a,b,c,d,e, f. This can however be more rapidly achieved by estimating the updated values for A for the next iteration from the previous values for A,B and D above as follows.

From the above for points within portions of the images f(x,y) and g(x,y) being matched

$$B=A\delta D+E$$

where $\delta D=(\delta A,\delta b,\delta c,\delta d,\delta e,\delta f)^T$ and A is a matrix whose ith

entry is $(xg^i_x, yg^i_x, g^i_x, xg^i_y, yg^i_y, g^i_y)$.

Noting that A is equal to the derivative of g with respect to the parameters (a,b,c,d,e,f), if after j iterations B_j, g_j, D_j and A_j are estimated values for B,g,D and A and assuming the patch in the first image f(x,y) stays fixed then after one iteration it is possible to determine

$$\delta D = D_1 - D_0 \text{ and}$$

$$\delta g = g_1 - g_0 \quad = (f_1 - g_1) - (f_0 - g_0)$$

$$= B_1 - B_0$$

which gives information about the derivative of g in the direction δD. Noting that, if

$$A\ \delta D = \delta g,$$

the derivative of g will satisfy the information obtained, it follows that an update of the iterative solution of A will be a reasonable solution where the above holds true. This can automatically be achieved by using the update.

$$A_j = A_{j-1} + (\delta g_j - A_{j-1}\delta D_j)\ (\delta D_j^T)/(\delta D_j^T \delta D_j)$$

where $\delta D_j = D_j - D_{j-1}$ and $\delta g_j = B_{j-1} - B_j$;

and hence by calculating for patches being matched an

initial difference matrix B_o and an initial derivative matrix A_o, an iterative solution for the transform T can be calculated solely by recalculating the difference matrix B_i for each iteration and updating the transform T and the derivative matrix using this recalculated difference matrix B_j in the manner described with this update being a reasonable approximation.

In this embodiment, the upper limit for the number of iterations is set to 10 and a patch is identified as having converged if the updated transform varies the x, y co-ordinates being matched by less than 0.03 pixels. In addition to checking whether convergence has been achieved, at each iteration in this embodiment a check is also made as to whether the calculated transform has failed either by introducing excessive expansion of an area, or varying the x, y co-ordinate of a potential match by 2 or more pixels or where a transform results in searching for a match outside the image area. If any of these conditions are met, this indicates that no realistic match will be reached.

When convergence is reached data identifying the number of iterations used to reach a result is stored. Alternatively if the transform fails, a negative number

identifying that one of the errors has occurred is stored for the point as an iteration result. Otherwise, a new iterative solution for the transform is then determined.

Thus when a patch is processed (S23) an iterative determination of the transform of the patch necessary to match the patch form image received from one of the geometry cameras 18 of a camera rig 1, 2, 3 with a corresponding patch in the image received from the other geometry camera 22 of the same camera rig 1,2 3 is made. Data for that point is then stored in the data store 47 where the iterative transform is stored as the current transform 64 the number of iterations utilised to determine the result or a negative error number is stored as the iteration result 66 a patch difference value being the absolute grey scale difference for the patch transformed in the manner identified by the current transform 64 compared with the corresponding patch in the image received from the other geometry camera 22 the process count 70 is incremented by one and the predicted/calculated flag 72 is set to calculated.

The processing module 42 then (S24) determines whether the match made for the point being processed is a good

match. In this embodiment this is achieved by utilising the iteration result data 66 of the patch. If, for any reason the number of iterations required to determine the transform 64 for matching the patch from one invention to the corresponding patch in the second image is too high or negative this indicates that it was not possible to determine a match for the point. If, however, this is not the case the processing module 42 utilises the transform 64 for the current point to act as seed data for initiating matches for adjacent points as will now be described in detail with reference to Figure 7B.

Initially (S25) the processing module selects one of the four adjacent points adjacent to the point corresponding to the patch which has just been processed. That is to say the points at which the x coordinates and y coordinates 60, 62 stored in the data store 47 are one greater and one less than the patch which the x coordinates and y coordinates 62, 62 for the patch which has just been processed.

When the adjacent point has been selected the processing module 42 then (S26) determines whether the process count 70 for that point is less than three. If this is the case this indicates that the adjacent point which has

been selected has not previously been processed more than three times. If the point has been processed three times, this indicates that there have been difficulties in generating a satisfactory match for the point. In order to speed the processing of images, in this embodiment under these circumstances the point is not considered for any further attempts at matching the point. In other embodiments the process count could be required to be a different value with the result more or fewer attempts at identifying a match for a point occur.

If the process count for a point is less than three, the processing module 42 then determines (S27) whether the selected point is associated with a negative iteration result 66. This could arise either because the point has never been processed before or because the processing module 42 failed to determine a match for the patch last time the patch was processed. If the iteration result 66 is negative, the processing module 42 sets the predicted/calculated flag 72 for the point being considered to be predicted and adds (S28) the point to the bottom of the queue.

Thus in this way, the processing module 42 causes a queue of points to be identified which enable portions of

the images received from the geometry cameras to be matched in a manner in which adjacent portions of an image are processed consecutively. The adding of points to queue in this manner also enables an ordering of points to be made which requires minimal processing power and as will be described in detail later, enables the best matches for adjacent points to be used as seed values for subsequent processing.

If the processing module 42 determines (S27) that the iteration result for a point is not negative, the processing module 42 then determines (S29) whether the adjacent point being tested has a predict/calculated flag set to predicted. If the predicted/calculated flag is set to calculated, this indicates that a transform for the point in question has already successfully been determined. However, if the predicated/calculated flag 72 is set to predicted, this indicates that the transform for the point identified by the current transform data 64 is only an initial estimate of a starting point for the transform necessary to match the patch identified by the x coordinate and y coordinate 62 of the selected adjacent point or when the point was processed previously, the processing module 42 failed to determine a satisfactory match for the point.

If the predict/calculated flag 72 is set to predicted the processing module 42 then (S30) compares the patch difference data 68 for the selected adjacent point with the calculated patch difference applying the current transform 64 of the previously processed point to the patch identified by the adjacent point being tested. If the application of the transform for the previous point which has been processed results in a better match between patches in the geometry images, this is indicated by the stored patch difference 68 for this adjacent point being greater than the calculated patch difference determined by applying the transform calculated for the previously processed point to the patch of the adjacent point being considered. If this is the case or alternatively automatically after adding a point associated with a negative iteration value to the queue of points to be processed (S28) the processing module 42 (S31) updates the patch difference data 68 and the current transform 64 for the adjacent point being considered by setting the current transform 64 for the adjacent point equal to the transform for the previously processed point and the patch difference 68 for the adjacent point to the calculated patch difference calculated utilising the transform for the previous point.

After either the processing module has determined (S29) that the calculated flag 72 of the point is set to calculated, or the processing module 42 has determined (S30) that the transform for the previously processed point is not an improvement on the match for the current transform 64 for the adjacent point being considered or (S31) the data for the adjacent point has been updated, the processing module 42 then (S32) determines whether all of the points adjacent to the point which has just been processed have been considered and updated if necessary. If this is not the case the next adjacent point is then considered (S25-S31). Thus in this way all of the four points adjacent to a point which is processed are considered one after another and the current transform data 64 for those adjacent points which have not already had satisfactory transforms calculated for them are updated to correspond to better initial estimates of transforms for those points.

Returning to Figure 7A after current transform data 64 for adjacent points has been updated the processing module 42 then (S33) determines whether the queue of points to be processed is empty. If this is not the case the next point in the queue is selected (S23) and a transform for that next point is calculated and estimates

of transforms are of adjacent points are updated where required (S24-S32).

If the queue of points is empty the processing module 42 then determines whether all of the points in the image responding to patches have been processed (S34) if this is not the case a new seed point (S21) is identified and further points are processed (S22-S33). When all of the points in the image have been processed (S34) the processing of the processing module comes to an end.

As an initial first approximation, it is reasonable to assume that adjacent parts of a patients body 8 are flat and orientated in the same direction relative to the cameras of the camera rigs 1, 2, 3. By processing patches in the images received from the geometry cameras 18, 22 in the way described above, when the orientation of one point within the image has been determined, this orientation is utilised in selecting an initial start point for calculating the orientation of adjacent points. As the best orientation of either an identity transform, the orientation for a point determined from a previous pair of images, or the orientation of adjacent processed points is used as a start point for determining the transform, the intensive processing necessary for the

iterative accurate determination of the orientation of points is minimised. The speed at which the processing module 42 is able to determine the orientation of the points appearing in the entire image is thereby increased.

Further, by adding a point to the queue of points for processing when, an adjacent point is processed and the iteration result 66 for the point being considered indicates that no satisfactory match has been determined, the processing module 42 ensures that all available seed data is utilised to attempt to find a match for each point. Specifically, if an initial attempt at a match fails, a point is tested again by using any subsequent seed data determined for any adjacent points. Further although no attempt is made to identify the highest quality matches and process those matches first, the present embodiment ensures that by the time a point is processed all available information for any adjacent points is taken into account when selecting an initial stating transform. The adding of points to a queue of points to be processed also ensures that adjacent areas are processed together.

Returning to Figure 6 when all the points in a pair of

images received from the two geometry cameras 18, 22 of the camera rig 1, 2, 3 have been processed, the processing module 47 then (S14) determines whether images for all three camera rigs 1, 2, 3 have been matched. If this is not the case the processing module 47 then selects the next set of geometry cameras 18, 22 (S15) and proceeds (S10-S14) to determine transformations to match portions of images received by the geometry cameras 18, 22 of that camera rig 1, 2, 3.

When transformations have been determined for all three pairs of geometry images for a frame the processing module 42 then (S16) proceeds to generate a three dimensional wire mesh model of the surface of a patient 8 utilising the calculated matches.

Specifically as is shown in detail of the flow diagram of Figure 9, the processing module initially (S40) utilises the current transform data 64 associated with points identified by the x coordinates 60 and the y coordinates 62 of data stored within the data store 47 for each pair of images together with the stored data identifying the relative orientations of the geometry cameras 18, 22 of the camera rigs 1, 2, 3 and intrinsic properties of those cameras 18,22 to generate three three dimensional wire

mesh models of the surface of a patient 8 as visible from the three camera rigs 1, 2, 3. In this embodiment the calculation of the wire mesh models of the surfaces as viewed from the three camera rigs 1, 2, 3 utilising this data is entirely conventional.

The processing model 42 then selects a first model for processing. The processing module (S41) then identifies a triangle from the selected model defined by points at the edge of the selected wire mesh model. The processing module then determines for the selected triangle the projection of the selected triangle into the image planes of the geometry cameras utilised to generate the other two models. The processing module then (S42) determines whether the selected triangle covered by a portion of the models generated from the other two camera rigs.

Specifically the processing module determines for each of the projections of the vertices of the selected triangle into the view points of the other camera rigs, whether projections are also represented by the model generated using image data from the camera rig represented by that image plane. If this is the case for all three of the projected vertices into a particular image plane, the processing module 42 then determines whether the

triangles from the model generated utilising that image plane correspond to triangles in space which are relatively close to the triangle in space represented by the model being processed. This will be the case where the projected triangle is in fact representative of the same portion of the surfaces of a patient as part of the model generated utilising that particular image plane.

If this is the case, the processing module 42 then (S43) determines whether the triangle being processed should be deleted. In this embodiment, a twofold test is utilised to determine whether a particular triangle should be deleted. The processing module 42 initially determines the relative orientation of the triangle being processed relative to the image plane utilised to generate that triangle. An angle identifying this relative orientation is then stored. The processing module 42 then makes a similar determination for the relative orientations of the triangles identified by the points of the vertices projected into the image plane used for the other models and for the triangles representing those vertices in the other models.

The triangle from the mesh being processed is then deleted if either the triangle from the mesh being

processed is determined to have an orientation greater than a current threshold orientation or the triangle is determined to be more oblique relative to the image planes utilised to generate the selected triangle than any of the orientations of the triangles from the other models identified by the projection of the selected triangle into the image plane utilised to generate those other models. In this embodiment the threshold value for deleting triangles is initially set at 90°. That is to say the processing module initially is arranged to delete triangles oriented at more than 90° to or away from the image plane utilised to generate a portion of the model.

If a triangle is determined to be completely represented by part of one of the other models and is determined to have been generated from data which is indicative of a more oblique angle than the threshold value or more oblique data than the data utilised to generate corresponding portions of the other models the processing module 42 then (S44) deletes that triangle from the stored model for the selected mesh.

After either triangle has been deleted or if it has been determined that a boundary triangle being considered is not represented by a portion of the other models or is

not determined to have been generated utilising data indicative of a more oblique angle than the other models, the processing module 42 then (S45) determines whether all of the triangles at the edge of the mesh being processed have been considered for possible deletion.

If this is not the case, the next boundary triangle in the currently selected mesh is selected and a determination whether to delete that triangle is made (S41-S44) when all of the triangles at the boundary of one mesh have been considered the processing module 42 then (S46) determines whether all three of the wire mesh models have been considered. If this is not the case the next mesh is selected (S47) and then each of the boundary triangles at the edge of the wire mesh model represented by that mesh are individually considered for possible deletion (S41-S46).

Thus in this way each of the triangles at the edge of all three meshes are considered and where the portion of a surface represented by the boundary triangle is determined to also be represented by other data, the triangle is deleted if it has been generated from more oblique data than the other data representing that portion of the surface.

After all three of the models have been considered in turn the processing module then (S48) determines whether in the latest round of processing any triangles have been deleted from the wire mesh models.

If this is the case the processing module 42 then (S49) determines whether the current threshold value for deleting triangles is set to its maximum level. In this embodiment the maximum level is set to 75°. If the current threshold value is not set at 75° the processing module 42 then (S50) reduces the threshold by a further 5° before proceeding to select the first model for processing utilising the reduced threshold (S47).

Thus in this way the criteria for deleting triangles from the various models are gradually reduced so that initially only the more oblique triangles which are represented by more than one wire mesh are removed. As the boundary triangles are processed at each iteration, the deletion of triangles will result in additional triangles being considered for deletion. This together with the relaxation of the deletion threshold causes the processing module to gradually reduce the extent of overlap of the surfaces represented by the three wire mesh models.

If after all of the meshes have been processed utilising a particular threshold, the processing module 42 determines (S48) that no deletions have occurred in the latest round of processing or alternatively if the threshold value for deleting triangles has reached its maximum value, the processed models will comprise models where only a very small portion of the surface at the edge of one particular model is also represented by data from the other two models. The processing module 42 then (S51) proceeds to merge these minimally overlapping wire mesh models in the manner described in "zippered polygon meshes from range images" Greg Turk and Marc Levoy, Computer Science Department, Stamford University. When all three models have been processed and merged into a single model, the combined 3D wire mesh model is then utilised to generate positioning instructions to position the patient 8.

Specifically returning to Figure 6 when a model has been generated by the image generation module 46 the control module 44 then (S17) determines whether the instructions received from the keyboard of the computer 5 indicate that the three dimensional wire mesh model data generated by the processing module 42 is to be utilised to position the patient automatically by sending instructions to the

mechanical couch 7. If this is the case the control module 44 passes data for the generated wire mesh model together with data for a stored model from an earlier treatment session retrieved from the data store 47 to the mechanical couch control module 45. The mechanical couch control module 45 then performs (S18) the automated generation of movement commands for the mechanical couch 7 in a two stage process.

Initially, the treatment couch control module 45 determines a first rough transformation for aligning the surface identified by the newly generated wire mesh model with the surface identified by the stored model. Specifically, the treatment control module 45 selects a subset of the vertices from the generated model together with a decimated wire mesh representation of the stored model. This decimated model is determined utilising conventional techniques such as are described in 'Decimation of Triangle Meshes' W. Schroeder et al Computer Graphics (SIGGRAPH '92) 26(2) pp65-70 August 1992.

For each sample vertex in the generated model, the closest vertex to the other decimated stored model is determined. The closest point on the surface defined by

the decimated model for the stored surface to each of the sample vertexes to the generated model is then calculated by considering each of the triangles including the identified closest vertex in the decimated model. When the closest points from the sample vertices to the decimated surface have been determined an initial transform to align the generated surface to the decimated surface is calculated utilising conventional Procrustes algorithm techniques such as are described in 'Least Square Fitting of Two 3D Point Sets' Arun et al, IEEE Transactions on Pattern Analysis and Machine Intelligence Vol PAMI-9 No.5 pp698-700, 1987, and 'Closed Form Solution of Absolute Orientation Using Unit Quaternions' B.K.P. Horn J. Opt-Soc. Am.A. Vol 4, No.4, pp629-642, April 1987. The process then iterates utilising the iterated closest point (ICP) algorithm as is described in "A Method for Registration of 3-D Shapes" Paul J. Besl and Neil D McKay, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol 14, No.2 February 1992 pp239-256.

When determining the initial transform in this way, in order to identify the closest vertex from one model to that in another, a comparison of the distance between all of the vertices in second model must be made. The time

necessary for such a determination is dependent upon the number of vertices the each model being searched. Thus by decimating the stored model using conventional techniques the numbers of vertices to be searched is reduced and hence the time taken for registration minimised.

After an initial transformation has been determined, the rough transformation is then refined by determining, for a sub-sampled selection of the vertices of the surface of the generated model to which the initial transformation has been applied, the projection of these vertices into the camera views utilised to generate the stored model. The closest vertex from the generated model to each of the vertices in the stored model is then determined by considering for each vertex in the generated model the projection of the vertex to the camera frames utilised to generate the stored model. The closest vertex being used in the stored model is then calculated using these determined closest pixels for each vertex. Having done this the ICP algorithm is repeated as described above to determine a final matching position.

The mechanical couch control module 45 then transmits to the mechanised couch 7 instructions to orientate the

couch 7 in order to account for the determined differences between the prestored model and the current generated model.

After any necessary movement commands have been generated, the models are then passed to the image generation module 46 so that images of the patient can be created and displayed (S19).

Specifically when a wire mesh model is received by the image generation model 46 the image generation module 46 checks with the control module 44 for a current display status then proceeds to generate as image of the patient 8 based upon the current display status.

One possible display status in this embodiment is a status for generating a texture rendered image utilising the texture data obtained from the texture cameras 20 of the camera rigs 1, 2, 3. In such a configuration the image generation module 46 causes the frame grabber 5 to obtain image data from the texture cameras 20 of the common rigs 1,2,3. The image generation module 46 then proceeds to texture render the generated three dimensional model received from processing module 42 utilising implicit texture render coordinates from the

images received the texture cameras 20 of the three camera rigs 1, 2, 3. Thus in this way an image of a patient 8 as currently viewed can be shown and displayed on the screen 11.

Alternatively in another configuration, the image generation module 46 might be arranged to generate a texture rendered image of the wire mesh model received from the processing module 42 based upon the relative differences of the positioning the surfaces of that wire mesh model relative to a previously stored wire mesh model of the patient 8 stored in the data store 47. Thus for example where the surface of the wire mesh model received from the processing unit 42 was above the corresponding portion of a surface of a stored model the surface of the model might be rendered red and where it was below the stored surface the surface might be rendered blue. Thus the image generated by the image generation module 46 would provide visual feedback to the operator to the relative positioning of the patient 8 during this and a simulation session.

Alternatively instead of a simple colour rendering of two colours, the extent to which a portion of a patient is above or below the stored surface might be indicated by

the relative variation in colouring ranging from a dark colour through a light colour where the hue of the rendering indicates the relative depth of the patient relative to the stored data. In such configurations texture render data for the model would be calculated based upon a comparison of the received wire mesh model and the stored model obtained from the data store 47.

After an image has been displayed the next frame of image data is then processed and further images are generated. In this way a series of images are presented to an operator providing real time visual feedback of the position of the patient.

Second Embodiment

After an image has been displayed the next frame of image data is then processed and further images are generated. In this way a series of images are presented to an operator providing real time visual feedback of the position of the patient.

A second embodiment of the present invention will now be described with reference to Figure 10. In the previous embodiment, an imaging system was described in which three camera rigs 1, 2, 3 are utilised to obtain image

data of a patient 8. In this embodiment, instead of an array of cameras 18, 20, 22 on a camera rig, image data is obtained utilising a self contained camera unit. The rest of the apparatus is unmodified.

Figure 10 is a schematic block diagram of a camera unit in accordance with this embodiment of the present invention. The camera unit comprises a set of three charged coupled devices (CCD's) 70, 71, 72. Each of the CCD's 70, 71, 72 in this embodiment comprise CCD's which do not have an asynchronous reset function. Associated with each of the CCD's 70, 71, 72 is a timer unit 80, 81, 82. The timer unit 81 of one of the CCD's 71 is connected to a master timing controller 85, so that the timer unit 81 can pass a vertical reset signal (VR) to the master timing controller 85. This timer unit 81 is also connected to the timer units of 80, 82 associated with the other two CCD's 70, 72 so that the pixel clock signals (PC) for timing the duration for reading data for each pixel from the CCD's arrays can be synchronised. The master timing controller 85 is also directly connected to the two other timing units 80, 82 and is also connected to a first and second flash unit 86, 87. In this embodiment, the first flash unit 86 is an ordinary flash and the second flash unit 87 is arranged

to project a speckle pattern for use in matching image points.

Each of the three CCD's is also connected to a analogue digital converter 90, 91, 92 to arrange to convert signals received from the respective CCD's 70, 71, 72 into a digital signal which is passed to a frame store 95. The frame store 95 comprises a latch 97 and a data store 98. The frame store 95 and the master timing controller 85 are both connected to a local area network (LAN) or other high speed interconnect so that the master timing controller 85 can receive control instructions from a controlling computer 5 and the frame store 95 can transmit image data via the LAN to the computer 5 where it is processed in a similar way to the data in the first embodiment. Additionally, the LAN provides means by which activation of three camera units can be synchronised so that as in the first embodiment simultaneous images of all sides of a patient can be obtained despite some portions of a patient being occluded in some viewpoints.

In use, when image data is to be obtained, the master timing controller 70, 71, 72 receives instructions from the LAN. These instructions indicate whether the CCD's are to be activated simultaneously or asynchronously.

If the CCD arrays are to be simultaneously activated an activation signal is automatically passed to all of the timer units 80, 81, 82 and is used to activate the first flash 86 simultaneously with the shutters of the CCD arrays 70-72. After a predetermined exposure period the shutters then close.

In order to synchronise the read out of data from the three CCD's, whenever a vertical reset signal is received by the master timing controller 85 from one of the timer units 81, the signal is automatically passed to the other two units. Due to the passing of the vertical reset signal (VR) via the master timing controller 85 the signals for each unit will not be quite simultaneous in that a very small difference in timing may occur but this difference is not significant. As the vertical reset signals (VR) and pixel clock signals (PC) used by the three CCD arrays 70-72 are identical, the A/D convertors 90-92 will read and pass to the latch 97 and datastore 98 pixel data which is synchronised and which corresponds to images obtained at the same time by all of the CCD arrays. Once a complete image has been stored in the data store 98 for all three arrays 70-72, the latch then releases the images from the data store 98 when instructed to do so by the master timing controller 85 on

the basis of instructions received from the LAN.

When asynchronous data is desired, the activation signal sent by the master timing controller 85 to the two flash units 86, 87 causes the first flash unit 86 to be activated shortly before the second flash 87 is activated. Simultaneously with the activation of the first flash 86, the timer unit 81 of one of the CCD's 71 causes the shutter on the associated CCD 71 array to open. Under control of the master timing controller 85, the second flash 87 is activated and the shutters of the other CCD's 70, 72 are opened for the duration of the second flash. In this embodiment the delay between the first and second flashes is made to be equal to a predetermined number of pixel clocks for example corresponding to 8 lines of read out from the CCD's 70-72. After a predetermined exposure period the shutters for all three CCD's close and image data from the CCD's are passed via their respective analogue digital converters 90, 91, to the frame store 95.

As the timer units 80-82 are synchronised, image data received via the analogue digital converters 90, 92 will also be synchronised. This will mean that image data from the two CCD's activated simultaneously 70, 72 will

represent image data obtained from the same instant. The majority of the image data obtained from the remaining CCD will also correspond to the shutter period for the two other CCD arrays 70, 72 except that the initial portion of the data signal transmitted via the analogue digital converter 91 will correspond to part of the CCD array 71 whilst the shutter was closed. By discarding this portion of the data, three images, two slightly smaller than the other one but all of which correspond to near simultaneous exposure of the three CCD arrays 70-72 can be obtained where two images comprise images of a speckle pattern and the third does not.

When a set of three images have been stored in the frame store 95 the image data can then be transmitted via the LAN to a computer 5 for processing. As this data is already in digital form, any suitable means of transmission, such as an ethernet can be utilised to transmit this data to the computer 5. The costs of cabling are thereby reduced. Further by providing a frame store 95, which is arranged to receive image data from the three CCD's 70-72, a means for obtaining simultaneous read-out from all three cameras is provided.

Although in this second embodiment a system has been

described in which image data is stored in a frame store 95 and transmitted via a LAN to a computer 5, it will be appreciated that a processing system could be incorporated within the camera unit so that a 3-D wire mesh model representing a surface could be transmitted rather than having the processing of image data occur remotely from the camera unit.

Further Embodiments and Modifications

Although in previous embodiments matching of image patches has been described based solely on a transform for accounting for different relative orientations of a portion of a patient being matched, it will be appreciated that additionally, factor such as variation in relative lighting and differences in gain for different cameras or other image sensors, could also be taken into account when processing data to match patches. The processing to account for such variation would be entirely conventional.

Although in the first embodiment a system has been described in which patches are matched by recalculating iterative transforms from the difference between patch values at different iterations, it will be appreciated that transform values could be determined in a

conventional way by updating both the difference matrix and the derivative matrix for patches at each iteration.

Although in the first embodiment a system identifying the isocentre of a treatment apparatus has been described utilising a cube having a striped exterior, other systems could be utilised. An advantage of the system described in the first embodiment is that the identification of points corresponding to lines on a flat surface can be achieved relatively easily.

An alternative system could utilise a single flat plate on to which as in the previous embodiment laser cross hairs identifying the isocentre of a treatment apparatus are projected. In the case of a flat plate, the projection of three lines identifying three planes meeting at the point corresponding to the isocentre would cause three lines defining a triangle to be seen when those lines were projected onto a flat plate held obliquely close to the isocentre. The positions of three corners of the triangle could then be identified from the images obtained by the camera rigs. The ortho centre of the triangle appearing in the images can then be calculated. This is necessarily a perpendicular projection of the isocentre onto the plane where the

plate was held. The distance of the plate from the isocentre can then be calculated utilising the determined distances between the points corresponding to the corners of the triangle.

Although in the first embodiment, obliqueness of data is utilised to delete overlapping portions of models other measures of goodness of match could be used. Thus for example the path difference could be used to select triangles for deletion.

Further, although in the first embodiment the projected triangles are used to identify corresponding portions of different models, in other embodiments could use the identified triangles as a starting point for identifying exact matches for corresponding parts of models.

Additionally, the test for deleting the triangle described in the first embodiment could be amended for example all triangles covered by others which are oriented at an angle greater than a threshold could be deleted. Alternatively, triangles could be required to be both above a threshold and worse than the corresponding triangles in order to be deleted.

Although in the previous embodiments systems have been described in which image processing of stereo images is utilised to generate models for positioning a mechanical couch, it will be appreciated that the processing system described has wider applicability.

In the radiotherapy field, in addition to generating positioning instructions, the data obtained could be utilised in a number of other ways. For example the detailed three-dimensional models could be utilised to perform contouring to help in the calculation of a treatment plan. As the generated contours will be based upon the accurate measurements obtained from the camera rigs 1, 2, 3. The resulting contours will be highly accurate so that an optimum treatment plan can be determined.

Alternatively, the models could be utilised to activate the treatment apparatus so that for example the breathing cycle of a patient could be monitored and the application of radiotherapy applied at the same point during the breathing cycle when the patient was closest to a planned treatment position. In such a system, the wire mesh model data generated would be utilised to control the treatment apparatus gating so that the synchronisation of

treatment and the breathing cycle could be achieved.

Further instead of matching the position of the patient so that treatment and planning are achieved with the patient in the same orientation, the present invention could be utilised to determine the differences in position of the patient so that diagnostic data such as Magnetic Resonance Imaging (MRI) or X-ray CT data from the same patient could be aligned with one another even when the patient was not in exactly position when different data types were obtained.

An additional use of the data identifying a patient's position would be in the control of the movement of the treatment apparatus so that collision between the apparatus and any portion of a patient's body could be avoided.

The invention is equally applicable to other applications where the fast generation of a three-dimensional model of an individual from camera images is desirable. In view of the speed of which models can be generated utilising the present invention, the present invention is particularly applicable for obtaining three-dimensional models of a moving individual to identify for example

muscular problems in physiology or sports imaging.

The present invention also has applications outside of the medical field for example in body scanning for clothes or machine vision more generally where three-dimensional monitoring of products, for example, production lines is desired. The modelling systems could also be utilised to obtain data for giving motion capture for generation of animation or alternatively for security applications matching the shape of individuals to confirm identity. In security systems the modelling unit could be arranged to monitor the content of images and model faces of detected individuals whenever a face was detected in received images.

Although the embodiments of the invention described with reference to the drawings comprise computer apparatus and processes performed in computer apparatus, the invention also extends to computer programs, particularly computer programs on or in a carrier, adapted for putting the invention into practice. The program may be in the form of source or object code or in any other form suitable for use in the implementation of the processes according to the invention. The carrier be any entity or device capable of carrying the program.

For example, the carrier may comprise a storage medium, such as a ROM, for example a CD ROM or a semiconductor ROM, or a magnetic recording medium, for example a floppy disc or hard disk. Further, the carrier may be a transmissible carrier such as an electrical or optical signal which may be conveyed via electrical or optical cable or by radio or other means.

When a program is embodied in a signal which may be conveyed directly by a cable or other device or means, the carrier may be constituted by such cable or other device or means.

Alternatively, the carrier may be an integrated circuit in which the program is embedded, the integrated circuit being adapted for performing, or for use in the performance of, the relevant processes.

CLAIMS

1. A method of image processing comprising the steps of:

receiving first and second images representative of the same object viewed from a first and a second view point;

storing for each point in an array of points in said first image, an estimated transform required to match a portion of said first image identified by said point corresponding to part of said object to the portion of said second image representative of the same part of said object;

identifying an initial seed point within said array and adding data identifying said seed point to a queue of data identifying points to be processed; and

sequentially processing each of points identified by said queue, by:

adding data to the end of said queue identifying points in said array which are adjacent to the point identified by data at the head of the queue and for which no calculated transform has been determined;

utilising said stored estimated transform for the point identified by data at the head of the queue to determine a calculated transform for said point to match

the portion of said first image identified by said point to said corresponding portion of said second image; and

updating said stored estimated transforms for adjacent points in said array to said point for which a calculated transform is determined utilising said calculated transform.

2. A method in accordance with claim 1 wherein said updating of stored estimated transforms comprises the steps of:

determining a first value indicative of the correspondence between said portion of said first image identified by said point and a portion of said second image identified by applying said stored estimated transform to said portion of said first image;

determining a second value indicative of the correspondence between said portion of said first image identified by said point and a portion of said second image identified by applying said calculated transform for said adjacent point to said portion of said first image; and

if said second value is indicative of a closer correspondence, replacing said stored estimated transform for said point with said calculated transform for said adjacent point.

3. A method in accordance with claim 2 wherein said first and said second images comprise grey scale images and said first and said second values comprise calculated difference in grey scale values between said portion of said first image and said identified portion of said second image.

4. A method in accordance with any of claims 1, 2 or 3, further comprising storing data identifying in said array the number of times data, each point is added to said queue and only adding data to said queue identifying a point if the said point has been added to said queue fewer than a predetermined number of times.

5. A method in accordance with any preceding claim wherein a stream of video images are received said stream of video images comprising pairs of images representative of the same object viewed from said first and said second view point, wherein said storage of an estimated transform for matching points in said pairs of images of said video stream comprises storing calculated transforms for said points in said array for a previous frame of images in said video stream.

6. A method in accordance with any preceding claim

wherein said determination of a calculated transform for a point comprises an iterative determination of a calculated transform, wherein the initial calculated transform for said first iteration corresponds to said stored estimated transform for said point.

7. A method in accordance with claim 6 wherein said iterative determination comprises determining at each iteration a value indicative of the correspondence between the portion of said first image identified by said point and a portion of said second image identified by applying said calculated transform for said iteration and aborting said calculation if said correspondence is greater than a predetermined threshold after a predetermined number of iterations.

8. A method in accordance with claims 6 or 7 wherein said iterative calculation further comprises at each iteration comparing a calculated iterative transform for said iteration with data identifying one or more transforms and aborting said calculation if said iterative calculation matches said stored data.

9. A method in accordance with any of claims 6-8 wherein said iterative determination comprises at each

iteration

determining a difference matrix identifying for each point in said portion of said first image identified by said point the difference in pixel values for said point and a corresponding point is said second image identified by applying to said points said calculated transform;

determining a derivative matrix identifying the rate of change of pixel values for said corresponding points in said second image; and

utilising said difference matrix and said derivative matrix to determine an updated transform.

10. A method in accordance with claim 9 wherein said determining a derivative matrix comprises:

for said first iteration determining said derivative matrix utilising said stored estimated transform; and

for subsequent iterations determining an estimated derivative matrix utilising the previous derivative matrix, and the differences between the previous and updated transforms and the differences between the previous difference matrix and an updated difference matrix calculated utilising said updated transform.

11. A method in accordance with any preceding claim further comprising the step of:

when said queue is empty, identifying a further seed point within said array for which no calculated transform has been determined and adding data identifying said further seed point to said queue.

12. A method in accordance with any preceding claim further comprising the steps of:

determining the relative positions of said first and second viewpoints;

illuminating a point in space utilising three intersecting planes of light;

providing an obstruction in the vicinity of said point;

obtaining first and second images of said obstruction illuminated by said intersecting planes of light;

processing said images to determine the relative positions of said first and second viewpoints to said illuminated point in space; and

utilising said determined transformations and positions to calculate the position of points in the surface of said object relative to said illuminated point in space.

13. A method in accordance with claim 12 wherein said

obstruction has a striped appearance and said processing of images comprises:

processing said images of said object to determine the positions of points corresponding to illuminated portions of said stripes appearing in said images relative to said first view point;

identifying groups of points lying within planes; and calculating the position of said point in space from the point of intersection of said planes defined by the positions of said groups of points.

14. A method in accordance with claim 12 wherein said obstruction comprises a flat surface and said processing of images comprises:

in said images identifying lines illuminated by said planes of light; and

utilising the positions of the intersections of said lines in said images to determine the relative positions of said first and second viewpoints and said point in space.

15. A method in accordance with any of claims 12-14 further comprising the step of:

storing data identifying points on a surface relative to a point in space;

determining a transformation required to match the surface identified by said calculated position of points with said stored surface.

16. A method in accordance with claim 15 wherein said determination comprises:

determining the projection of said stored points to said first view point;

determining for each of said projected stored points, the closest points in said array to said projected points; and

calculating said transformation for said surface on the basis of the transformations required to match each of said stored points to the points in space represented by the data for the points in the array determined to be closest to the respective projections of the stored points.

17. A method in accordance with claim 15 or 16 further comprising generating movement instructions to cause the surfaces of the object in said images to be aligned relative to said illuminated point in the same manner as said stored surface is aligned relative to a point in space.

18. A method in accordance in the claim 15 or 16 further comprising generating an activation signal when said calculated transformation is indicative of a transformation of less than a predetermined distance.

19. A method in accordance with any preceding claim further comprising:

obtaining model data indicative of the surface of said object viewed from a third view point;

utilising said calculated transforms to generate model data indicative of the surface of said object viewed from said first and second viewpoints; and

determining portions of said obtained model represented by said generated model by identifying projections of portions of said obtained model which project to said first view point and comparing the position of portions of said generated model corresponding to said projections.

20. A method in accordance with claim 19 further comprising deleting portions of said obtained model determined to be represented by said generated model wherein said portions of said obtained model are represented by data indicative of surfaces generated from data obtained from oblique images.

21. A method in accordance with claim 20 wherein said oblique images are determined utilising said calculated transforms for said points in said array in said first image corresponding to said portions of said model.

22. A method in accordance with claims 20 or 21 further comprising:

generating a combined model from said obtained and generated models from which portions have been deleted.

23. Image processing apparatus comprising:

a receiver operable to receive first and second images representative of the same object viewed from a first and a second view point;

a data store operable to store for each point in an array of points in a said first image, an estimated transform required to match a portion of said first image identified by said point corresponding to part of said object to the portion of a said second image representative of the same part of said object received by said receiver;

a queue store operable to store data identifying points to be processed;

an identification unit operable to identify an initial seed point within a said array and adding data identifying said seed point to a queue of data

identifying points stored in said queue store; and

processing unit operable sequentially processing each of points identified by a queue stored in said queue store, by:

adding data to the end of said queue stored in said queue store identifying points which are adjacent to the point identified by data at the head of the queue and for which no calculated transform has been determined;

utilising said estimated transform stored in said data store for the point identified by data at the head of the queue stored in said queue store to determine a calculated transform for said point to match the portion of said first image identified by said point to said corresponding portion of a said second image received by said receiver; and

updating said estimated transforms stored in said data store for adjacent points in said array to said point for which a calculated transform is determined utilising said calculated transform.

24. An apparatus in accordance with claim 23 wherein said processing unit is operable to update estimated transforms stored in said data store for points by:

determining a first value indicative of the correspondence between said portion of a said first image received by said receiver identified by said point and

a portion of a said second image received by said receiver identified by applying said estimated transform stored for said point by said data store to said portion of said first image;

determining a second value indicative of the correspondence between said portion of said first image received by said receiver identified by said point and a portion of said second image received by said receiver identified by applying said calculated transform for said adjacent point to said portion of said first image; and

if said second value is indicative of a closer correspondence, replacing said stored estimated transform for said point with said calculated transform for said adjacent point.

25. An apparatus in accordance with claim 24 wherein said receiver is operable to receive first and said second images comprising grey scale images and said processing unit is operable to calculate as said first and said second values, calculated difference in grey scale values between said portion of said first image and said identified portion of said second image.

26. An apparatus in accordance with any of claims 23, 24 or 25, wherein said data store is further operable to store for each point data identifying in said array the

number of times data, each point is added to said queue, said processing unit being operable to add data to said queue identifying a point only if the said point has been added to said queue fewer than a predetermined number of times.

27. An apparatus in accordance with any of claims 23-26, wherein said receiver is operable to receive a stream of video images comprising pairs of images representative of the same object viewed from said first and said second view point, wherein said data store is responsive to receipt of a new pair of images to store an estimated transform for matching points in said pairs of images of said video stream comprising calculated transforms for said points in said array for the previous frame of images in said video stream.

28. An apparatus in accordance with any of claims 23-27, wherein said processing unit is operable to determine a calculated transform for a point by performing an iterative determination of said calculated transform, wherein the calculated transform for said first iteration corresponds to said estimated transform for said point stored in said data store.

29. An apparatus in accordance with claim 28 wherein

said processing unit is operable to determine at each iteration a value indicative of the correspondence between the portion of a said first image identified by said point and a portion of a said second image identified by applying said calculated transform for said iteration and aborting said calculation if said correspondence is greater than a predetermined threshold after a predetermined number of iterations.

30. An apparatus in accordance with claims 28 or 29 wherein said processing unit is operable to compare at each iteration a calculated iterative transform for said iteration with data identifying one or more transforms and aborting said calculation if said iterative calculation matches said stored data.

31. An apparatus in accordance with any of claims 28-30 wherein said processing unit is operable to determine at each iteration:

a difference matrix identifying for each point in a said portion of said first image identified by said point the difference in pixel values for said point and a corresponding point is said second image identified by applying to said points said calculated transform;

a derivative matrix identifying the rate of change of pixel values for said corresponding points in said

second image; and

an updated transform determined utilising said difference matrix and said derivative matrix.

32. An apparatus in accordance with claim 30 wherein said processing unit is operable to determine a derivative matrix for a first iteration utilising said stored estimated transform; and

for subsequent iterations determine a derivative matrix utilising the previous derivative matrix, and the differences between the previous and updated transforms and the differences between the previous difference matrix and an updated difference matrix calculated utilising said updated transform.

33. An apparatus in accordance with any of claims 23-32 wherein said processing unit is operable when said queue is empty to cause said identification unit to identify a further seed point within said array for which no calculated transform has been determined and adding data identifying said further seed point to said queue stored in said queue store.

34. An apparatus in accordance with any of claims 23-33 further comprises:

a determination unit operable to determine the

relative positions of said first and second viewpoints;

lasers operable to identify a point in space by illuminating said point utilising three intersecting planes of light; and

an obstruction provided in the vicinity of said identified point; wherein received images of said obstruction illuminated by said lasers received by said receiver are utilised to determine the relative positions of said first and second viewpoints to said illuminated point in space.

35. An apparatus in accordance with claim 34 wherein said obstruction has a striped appearance and said processing unit is operable to:

process said images of said object received by said receiver to determine the positions of points corresponding to illuminated portions of said stripes appearing in said images relative to said first view point; and to

identify groups of points lying within planes; and calculate the position of said point in space from the point of intersection of said planes defined by the positions of said groups of points.

36. An apparatus in accordance with claim 34 wherein said obstruction comprises a flat surface and said

processing unit is operable to:

identify lines illuminated by said planes of light in images received by said receiver; and

to utilise the positions of the intersections of said lines in said images to determine the relative positions of said first and second viewpoints and said point in space.

37. An apparatus in accordance with any of claims 34-36 further comprising:

a model store operable to store data identifying points on a surface relative to a point in space; and

a calculation unit operable to determine a transformation required to match a surface identified by said calculated position of points calculated by said processing unit utilising said calculated transformations and a surface identified by data stored in said model store.

38. An apparatus in accordance with claim 37 wherein said calculation unit is operable to:

determine the projection of said calculated points to a defined view point associating said points identified in said stored model in said model store with points of an array associated with said view point;

determine for each of said projected calculated

points, the closest points in said array to said projected points; and

calculating said transformation for said surface on the basis of the transformations required to match said calculated points to the points in space represented by the stored data in said model store associated with the points in said array determined to be closest to the respective projections of the calculated points.

39. An apparatus in accordance with claim 37 or 38 wherein said calculation unit is operable to generate movement instructions to cause the surfaces of the object in said images to be aligned relative to said illuminated point in the same manner as said surface represented by data stored in said model store is aligned relative to a point in space.

40. An apparatus in accordance with claim 37 or 38 wherein said calculation unit is operable to generate an activation signal when said determined transformation is indicative of a transformation of less than a predetermined distance.

41. An apparatus in accordance with any of claims 23-40 wherein said apparatus further comprises:

a merging unit operable to obtain model data

indicative of the surface of said object viewed from a third view point; and

determine portions of said obtained model represented by a said generated model generated utilising said transforms calculated by said processing unit, by identifying projections of portions of said obtained model which project to said first view point and comparing the position of portions of said generated model corresponding to said projections.

42. An apparatus in accordance with claim 41 further comprising a deletion unit operable to delete portions of said obtained model determined by said merging unit to be represented by said generated model wherein said portions of said model are represented by data indicative of surfaces generated from data obtained from oblique images.

43. An apparatus in accordance with claim 42 wherein said deletion unit is operable to determine whether data is obtained from oblique images utilising said calculated transforms for said points in said array in said first image corresponding to said portions of said model.

44. An apparatus in accordance with claims 42 or 43 wherein said merging unit is operable to generate a

combined model from said obtained and generated models from which portions have been deleted.

45. A method of image processing comprising:

obtaining a stream of video images representative of the same object viewed from a first and a second view point;

for each pair of frames representative of said object determining for an array of points of an image from said first view point corresponding points in an image from said second view point representative of the same part of said object; and

generating a model of the surface of said object utilising the correspondence between points in said pairs of frames, wherein said determination of corresponding points comprises:

storing for each point in an array of points in said first image an estimated transform received to match a portion of said first image identified by said point corresponding to part of said object to the portion of said second image representative of the same part of said object and utilising said estimated transforms to determine said corresponding parts, wherein the initial estimated transforms comprise calculated transforms for matching corresponding points in an earlier pair of image frames.

46. A method of determining corresponding portions of models representing the surface of the same object comprising:

obtaining model data representative of the surface of an object viewed from a first and a second view point;

determining a projection of model data representative of an object viewed from said first object to said second view point;

determining for said projected data whether any portion of said model data representative of said object viewed from said second view point also projects to the same portion of said second view point; and

determining for portions of said models projecting to the same portion of said view point, whether the surfaces represented by said portions of said models are close to one another.

47. A method of aligning two models of surfaces comprising:

obtaining model data representative of a first and a second model;

determining for a plurality of points represented by said first model, the projection of said points to a predefined view point;

for said projected points, determining for said second model, the points of said second model, which

project to said predefined view point in the vicinity of projected points from said first model; and

determining an alignment transform for aligning said models on the basis of determined transforms for matching the points projected from said first model to the closest points projected from said second model.

48. A patient positioning system comprising:

means for obtaining a stream of images of a patient as a mechanical couch from a plurality of viewpoints;

means for processing frames of images from said plurality of viewpoints to generate for each frame a model of the surface of said patient; and

means for determining patient positioning instructions on the basis of models generated by said means for processing.

49. Apparatus for obtaining synchronous and asynchronous images of an object from a plurality of viewpoints, said apparatus comprising:

a plurality of imaging devices, each imaging device comprising an array of charge coupled devices, a shutter and a timing unit;

a control unit operable to vary the timing of the opening of said shutters and the read out of image data from said imaging devices; and

a frame store operable to receive image data from said imaging devices;

wherein the timing unit of one of said imaging devices is operable to synchronise the read out of image data from said charge coupled devices and said control unit is operable to initiate the opening of said shutters such that image data obtained from said arrays of charge coupled devices corresponds to images obtained whilst said all of said shutters are open or to delay the opening of said shutters of at least one imaging device relative to the others wherein the read out of data is synchronised with the earliest opening of said shutters.

50. Apparatus in accordance with claim 49, wherein said control unit further comprises recognition means for identifying the presence of an object in image data obtained from said arrays of charge coupled devices wherein said control unit is operable to initiate asynchronous image capture when the present of an object is detected.

51. Modelling apparatus comprising:

apparatus for obtaining image data in accordance with claim 49; and

image processing apparatus in accordance with any of claims 23 to 44.

52. A data carrier storing computer implementable process steps for generating within a programmable computer an image processing apparatus in accordance with any of claims 23 to 44.

53. A data carrier storing computer implementable process steps for causing a programmable computer to perform an image processing method in accordance with any of claims 1 to 22.

54. A data carrier in accordance with claim 52 or 53, comprising a computer disc.

55. A data carrier in accordance with claim 52 or 53, comprising an electric signal transferred via the Internet.

56. A computer disc in accordance with claim 54, wherein said computer disc comprises an optical, magneto-optical or magnetic disc.

57. A method of positioning a patient substantially as herein described with reference to the accompanying drawings.

58. Apparatus for positioning a patient as herein

described with reference to the accompanying drawings.

ABSTRACT

IMAGE PROCESSING SYSTEM FOR USE WITH A PATIENT POSITIONING DEVICE

Three camera rigs (1, 2, 3) are connected by wiring (4) to a computer (5). The computer (5) is also connected to a treatment apparatus (6). A mechanical couch (7) is provided as part of the treatment apparatus (6) such that under the control of the computer (5) the relative positions of the mechanical couch (7) and the treatment apparatus (6) may be varied. The camera rigs (1, 2, 3) obtain video images of a patient (8) lying on the mechanical couch (7) the computer (5) processes these images to generate a three-dimensional model of the surface of the patient which is utilised to position the patient relative to the treatment apparatus (6).

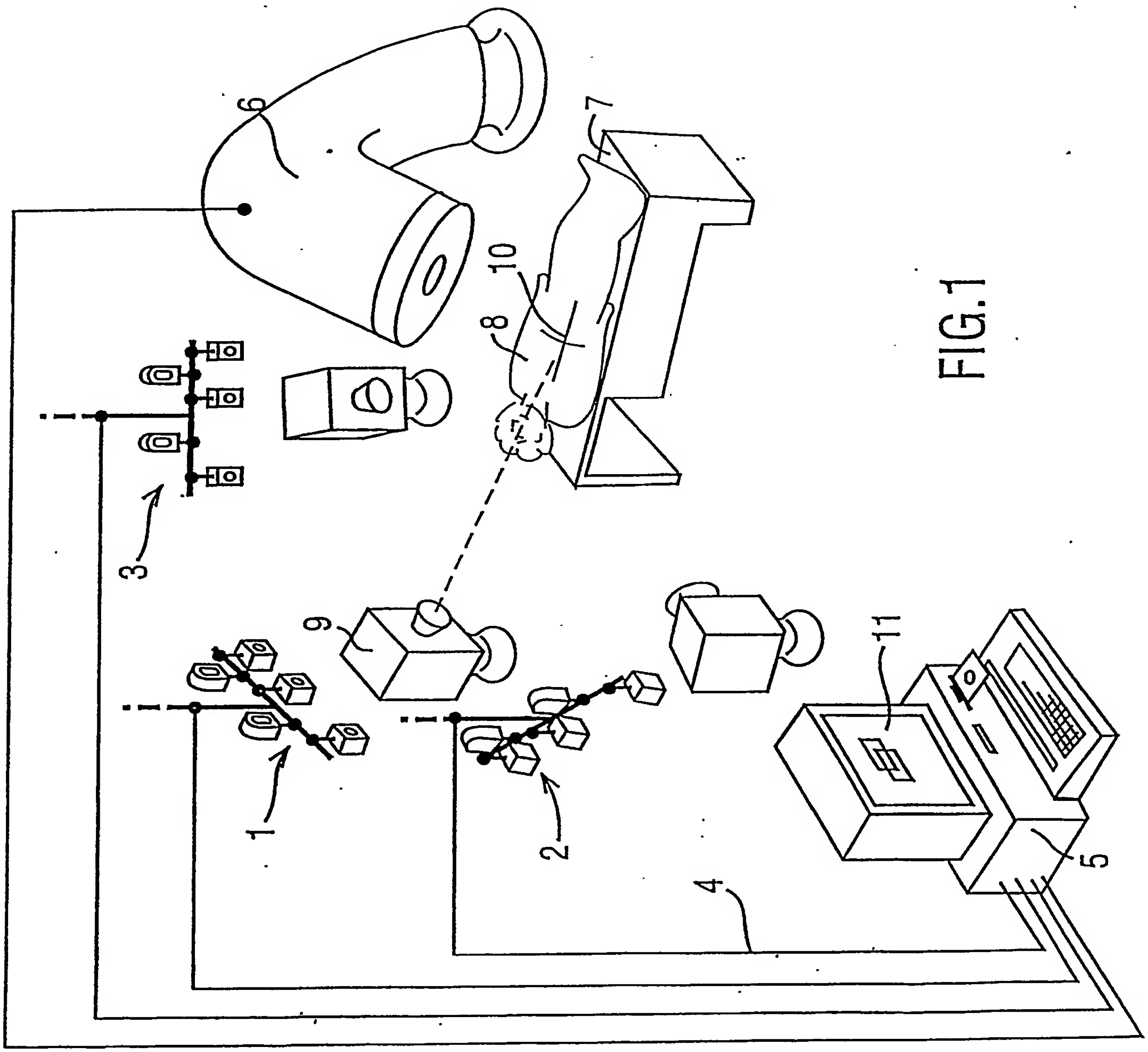
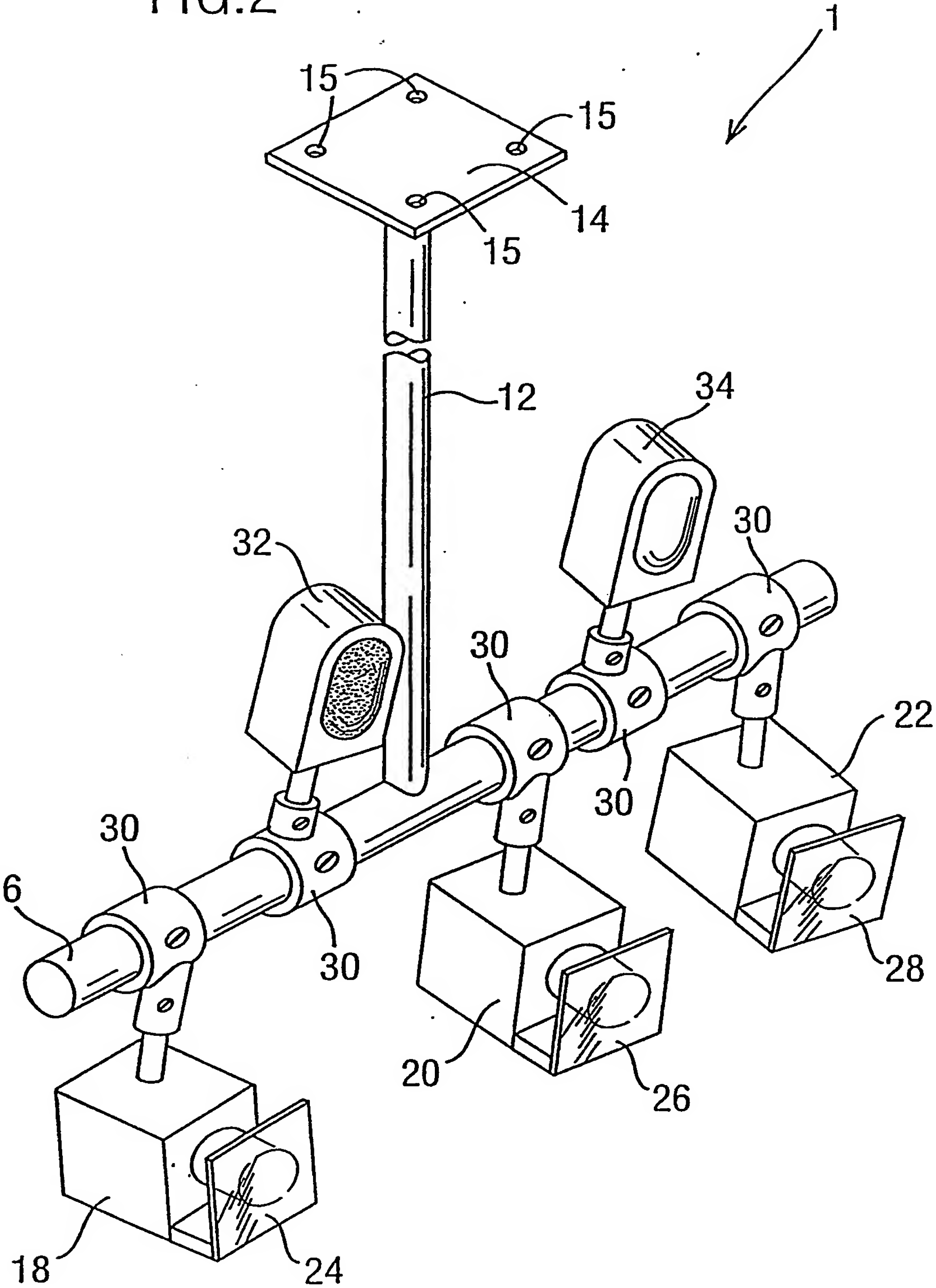


FIG.1

FIG.2



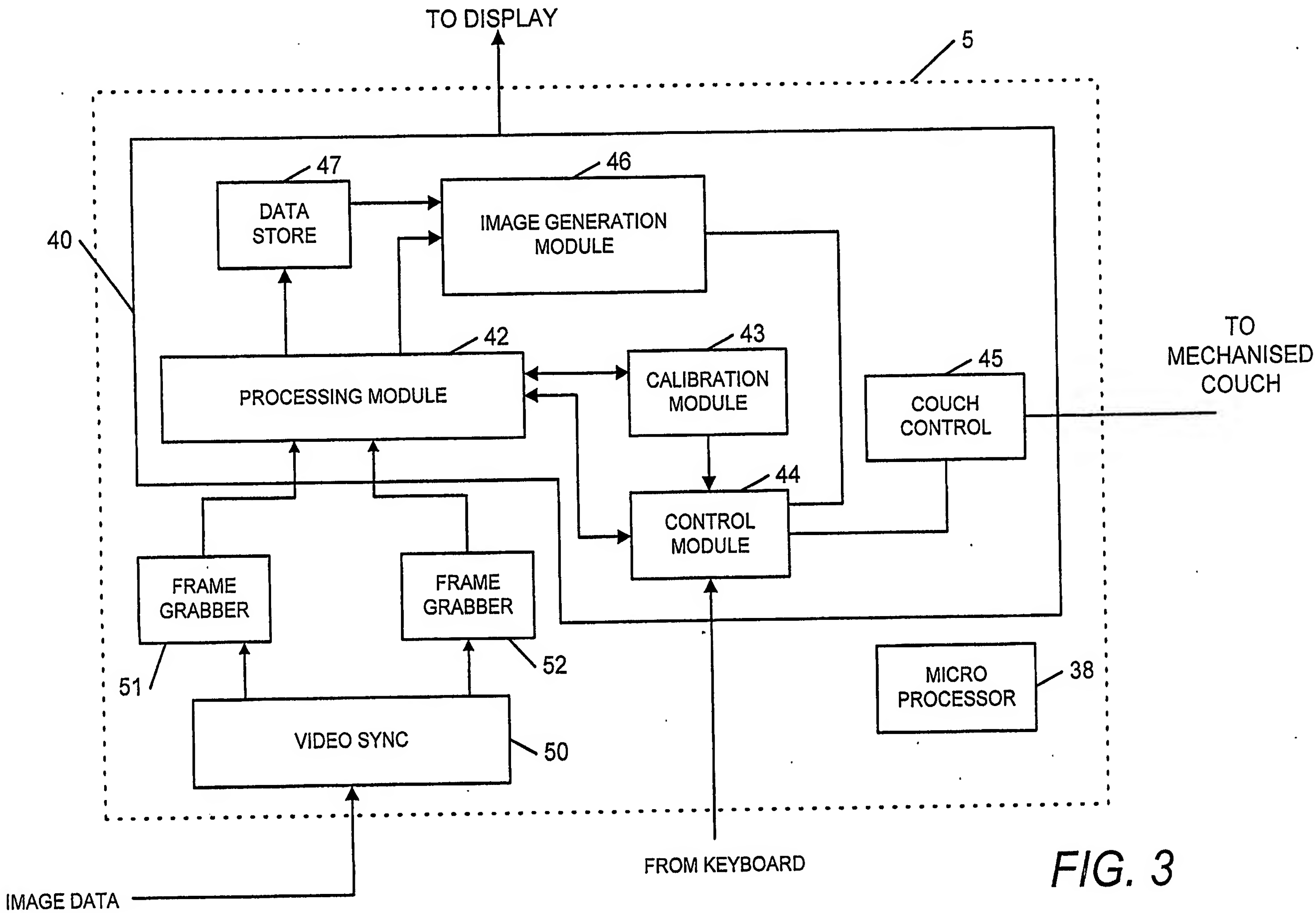

TO DISPLAY
5
40
DATA STORE
47
IMAGE GENERATION MODULE
46
PROCESSING MODULE
42
CALIBRATION MODULE
43
COUCH CONTROL
45
TO MECHANISED COUCH
CONTROL MODULE
44
FRAME GRABBER
51
FRAME GRABBER
52
VIDEO SYNC
50
MICRO PROCESSOR
38
IMAGE DATA
FROM KEYBOARD

FIG. 3

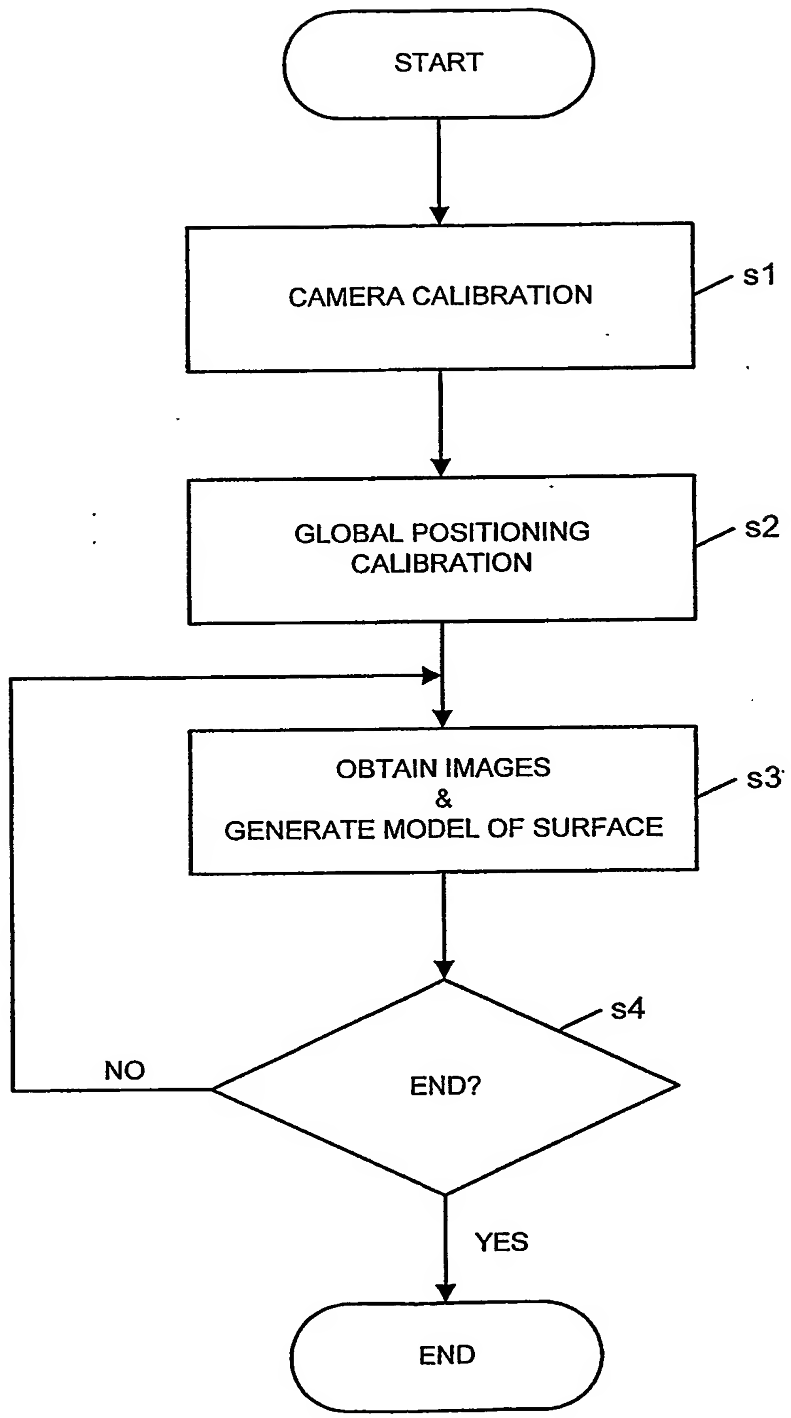

START
CAMERA CALIBRATION
s1
GLOBAL POSITIONING CALIBRATION
s2
OBTAIN IMAGES & GENERATE MODEL OF SURFACE
s3
END?
s4
NO
YES
END

FIG. 4

FIG.5A

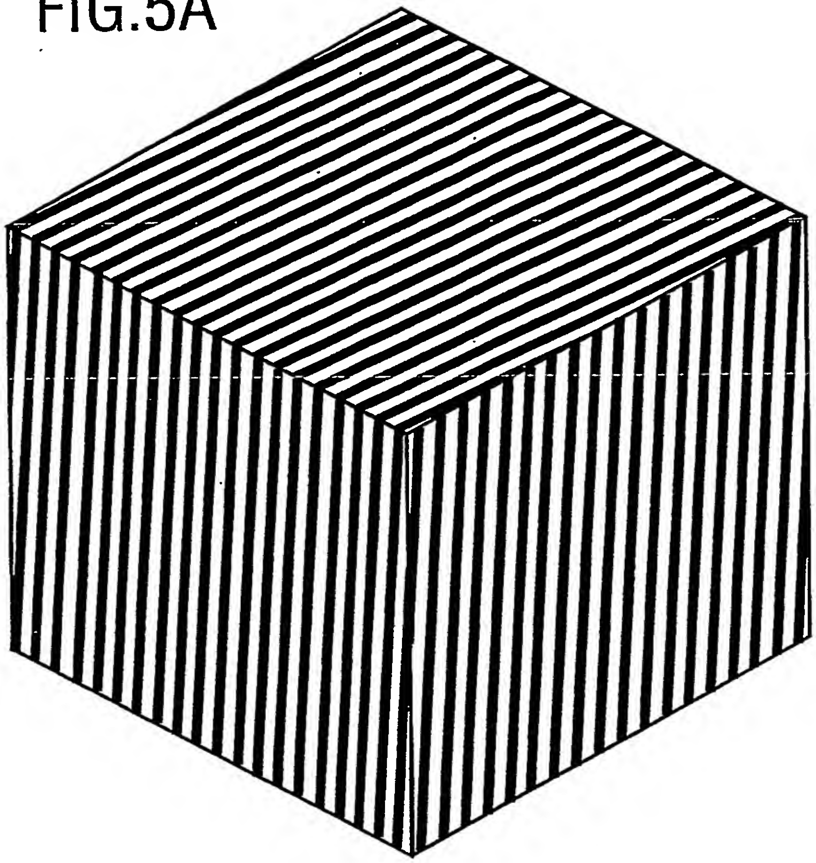
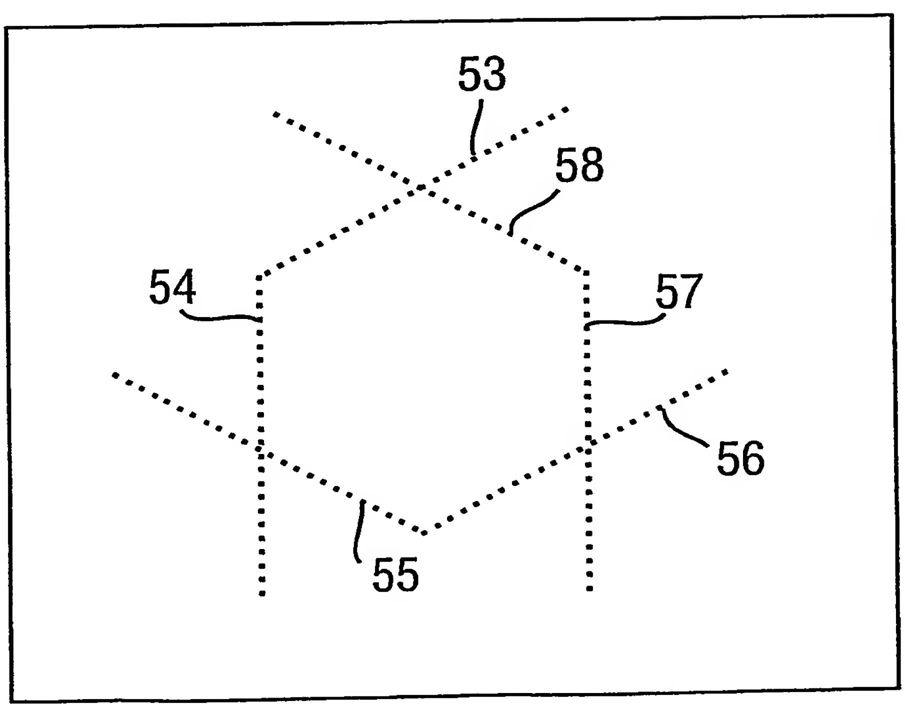


FIG.5B



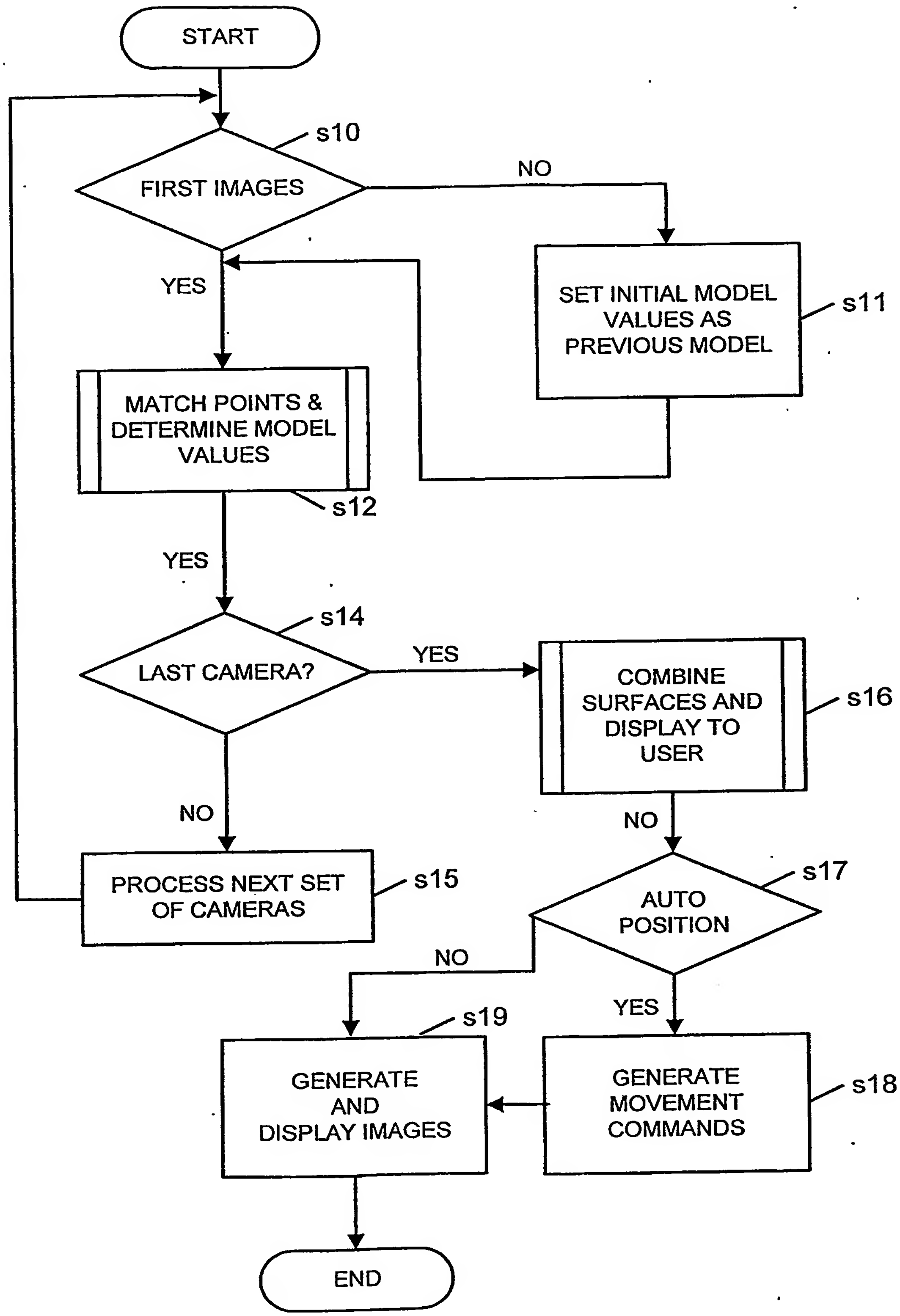

START
FIRST IMAGES
s10
NO
YES
SET INITIAL MODEL VALUES AS PREVIOUS MODEL
s11
MATCH POINTS & DETERMINE MODEL VALUES
s12
YES
LAST CAMERA?
s14
YES
COMBINE SURFACES AND DISPLAY TO USER
s16
NO
PROCESS NEXT SET OF CAMERAS
s15
NO
AUTO POSITION
s17
NO
YES
GENERATE AND DISPLAY IMAGES
s19
GENERATE MOVEMENT COMMANDS
s18
END

FIG. 6

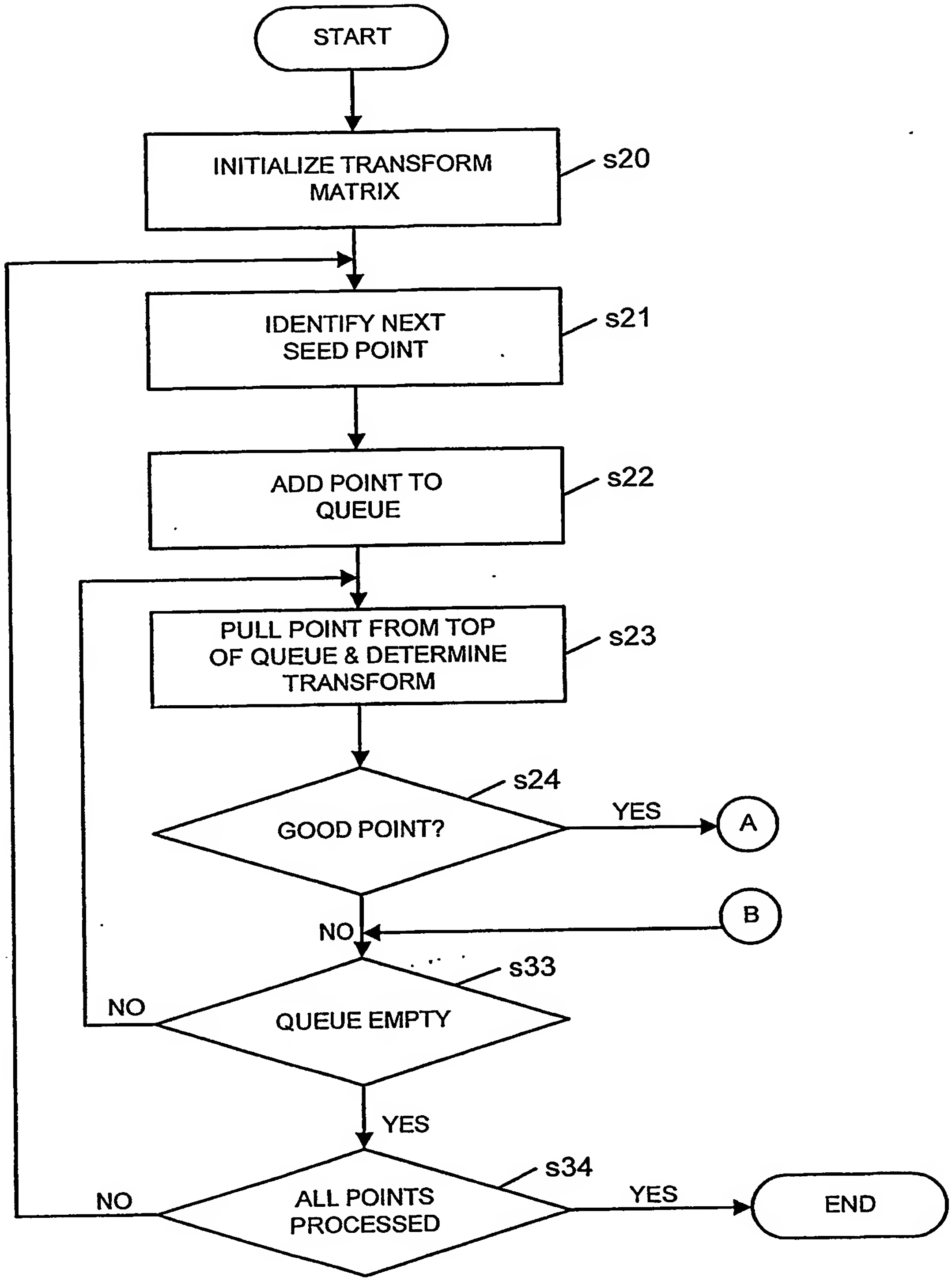

START
INITIALIZE TRANSFORM MATRIX
s20
IDENTIFY NEXT SEED POINT
s21
ADD POINT TO QUEUE
s22
PULL POINT FROM TOP OF QUEUE & DETERMINE TRANSFORM
s23
s24
GOOD POINT?
YES
A
B
NO
s33
NO
QUEUE EMPTY
YES
s34
NO
ALL POINTS PROCESSED
YES
END

FIG. 7A

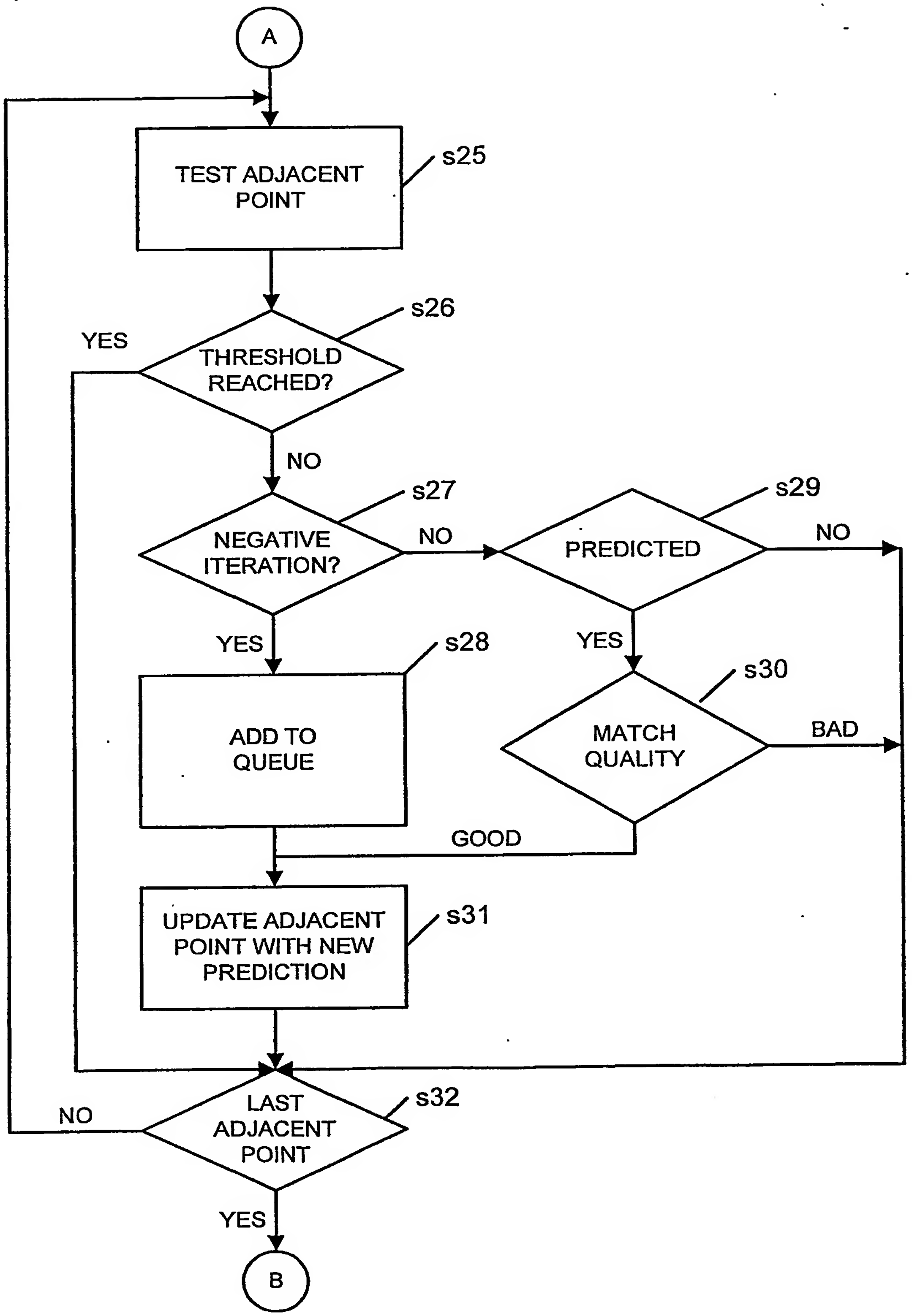

A
TEST ADJACENT POINT
s25
THRESHOLD REACHED?
s26
YES
NO
NEGATIVE ITERATION?
s27
NO
PREDICTED
s29
NO
YES
ADD TO QUEUE
s28
YES
MATCH QUALITY
s30
BAD
GOOD
UPDATE ADJACENT POINT WITH NEW PREDICTION
s31
LAST ADJACENT POINT
s32
NO
YES
B

FIG. 7B

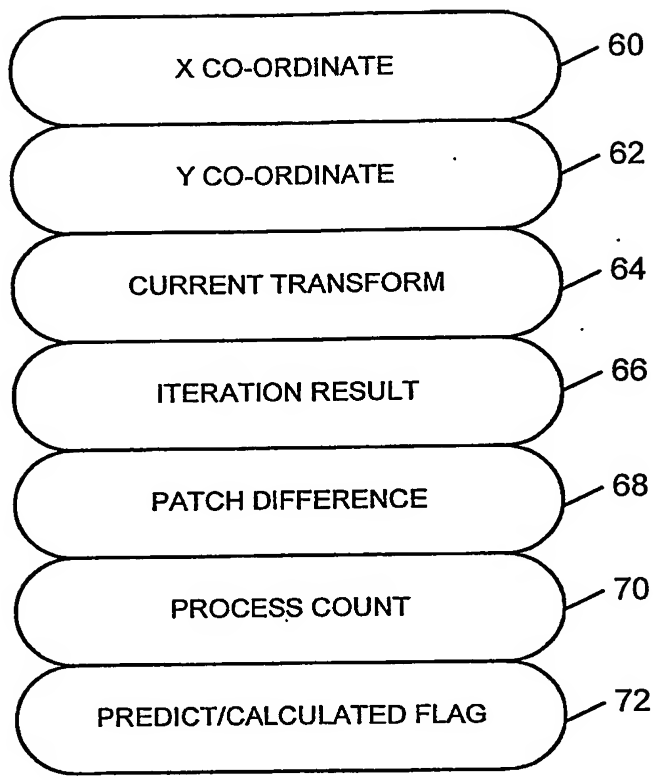

X CO-ORDINATE
60
Y CO-ORDINATE
62
CURRENT TRANSFORM
64
ITERATION RESULT
66
PATCH DIFFERENCE
68
PROCESS COUNT
70
PREDICT/CALCULATED FLAG
72

FIG. 8

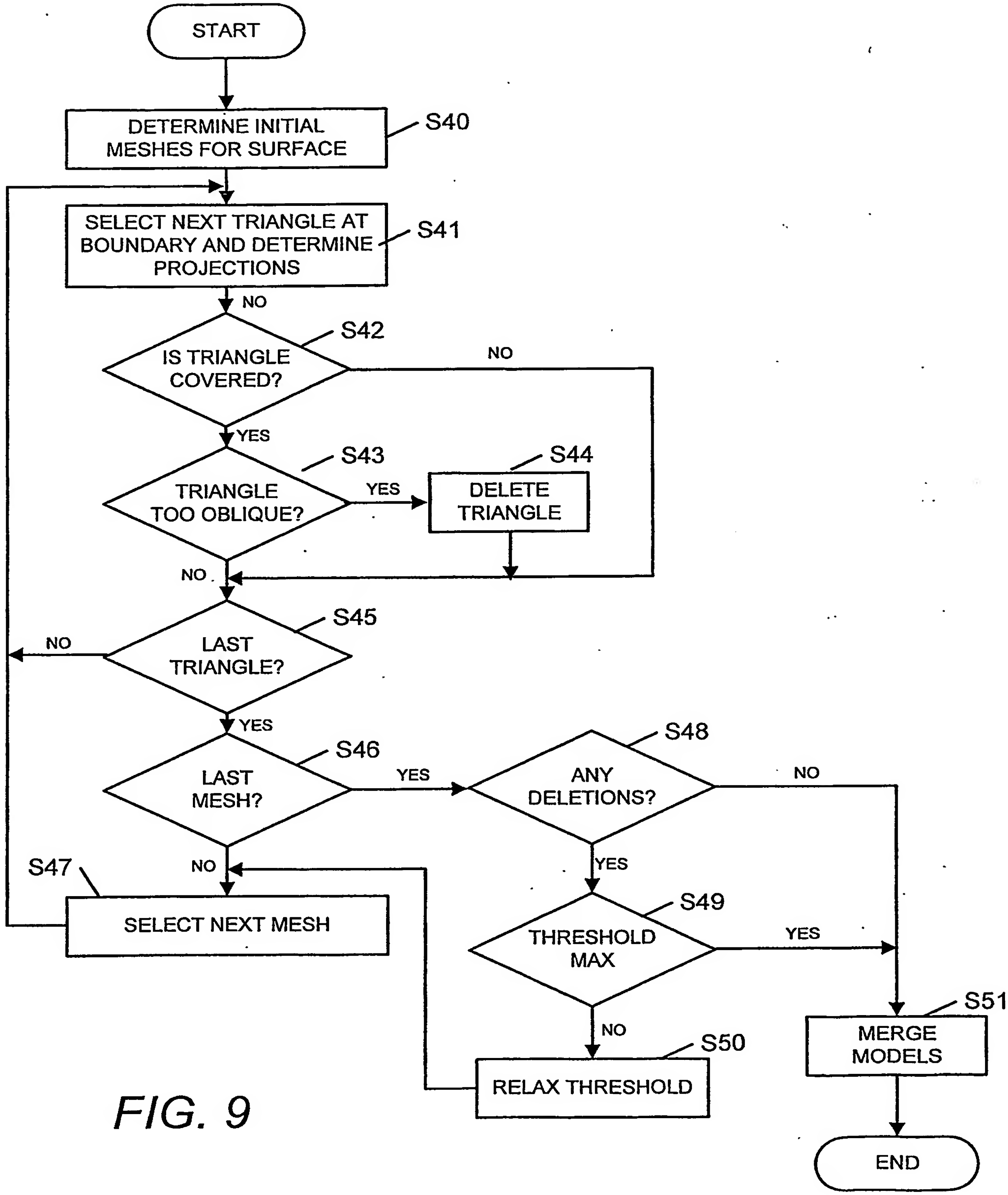
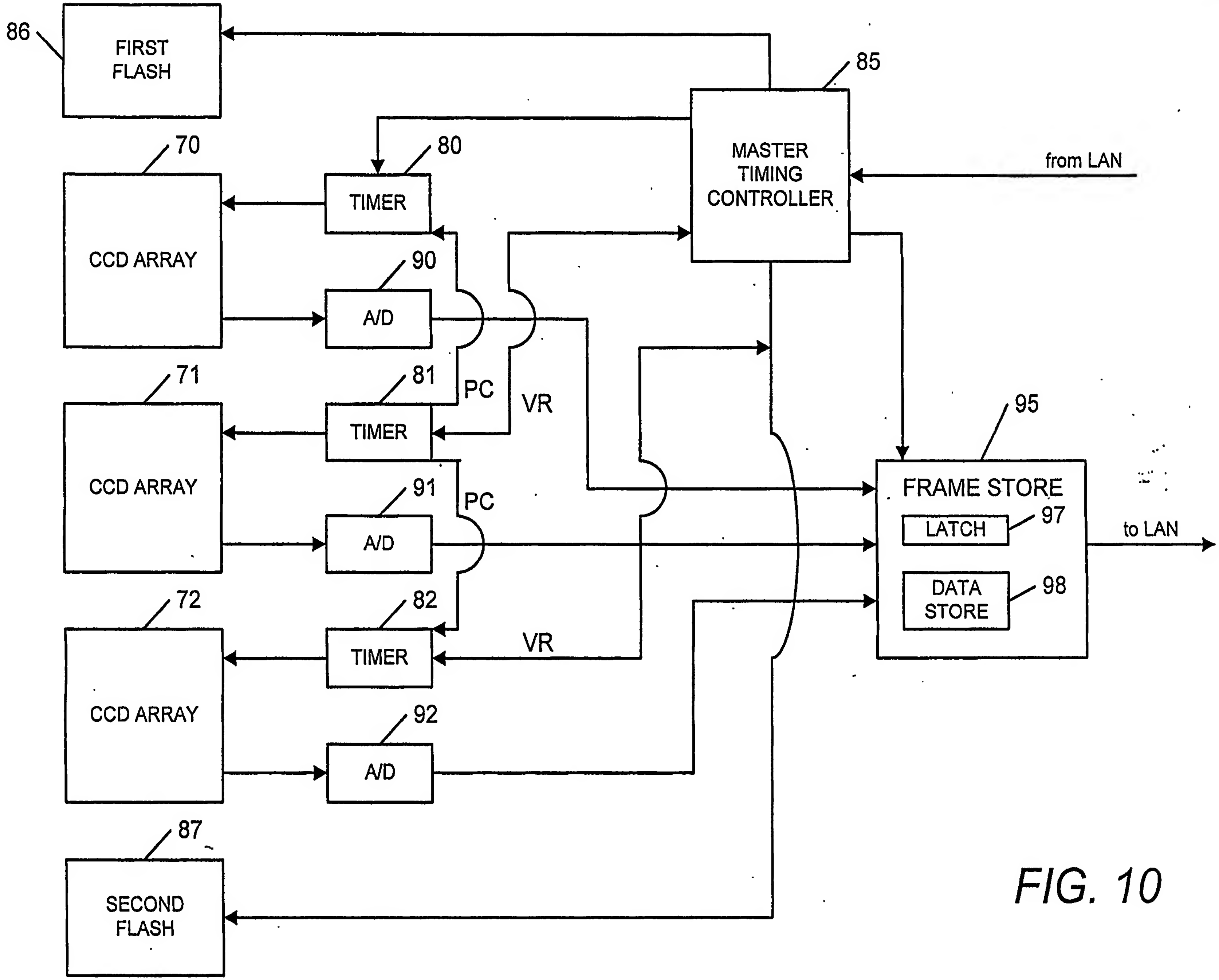

START
DETERMINE INITIAL MESHES FOR SURFACE
S40
SELECT NEXT TRIANGLE AT BOUNDARY AND DETERMINE PROJECTIONS
S41
NO
IS TRIANGLE COVERED?
S42
NO
YES
TRIANGLE TOO OBLIQUE?
S43
YES
DELETE TRIANGLE
S44
NO
LAST TRIANGLE?
S45
NO
YES
LAST MESH?
S46
YES
ANY DELETIONS?
S48
NO
YES
S47
NO
SELECT NEXT MESH
THRESHOLD MAX
S49
YES
NO
RELAX THRESHOLD
S50
MERGE MODELS
S51
END

FIG. 9



86
FIRST FLASH
70
CCD ARRAY
80
TIMER
90
A/D
71
CCD ARRAY
81
TIMER
PC
VR
91
A/D
PC
72
CCD ARRAY
82
TIMER
VR
92
A/D
87
SECOND FLASH
85
MASTER TIMING CONTROLLER
from LAN
95
FRAME STORE
97
LATCH
98
DATA STORE
to LAN

FIG. 10